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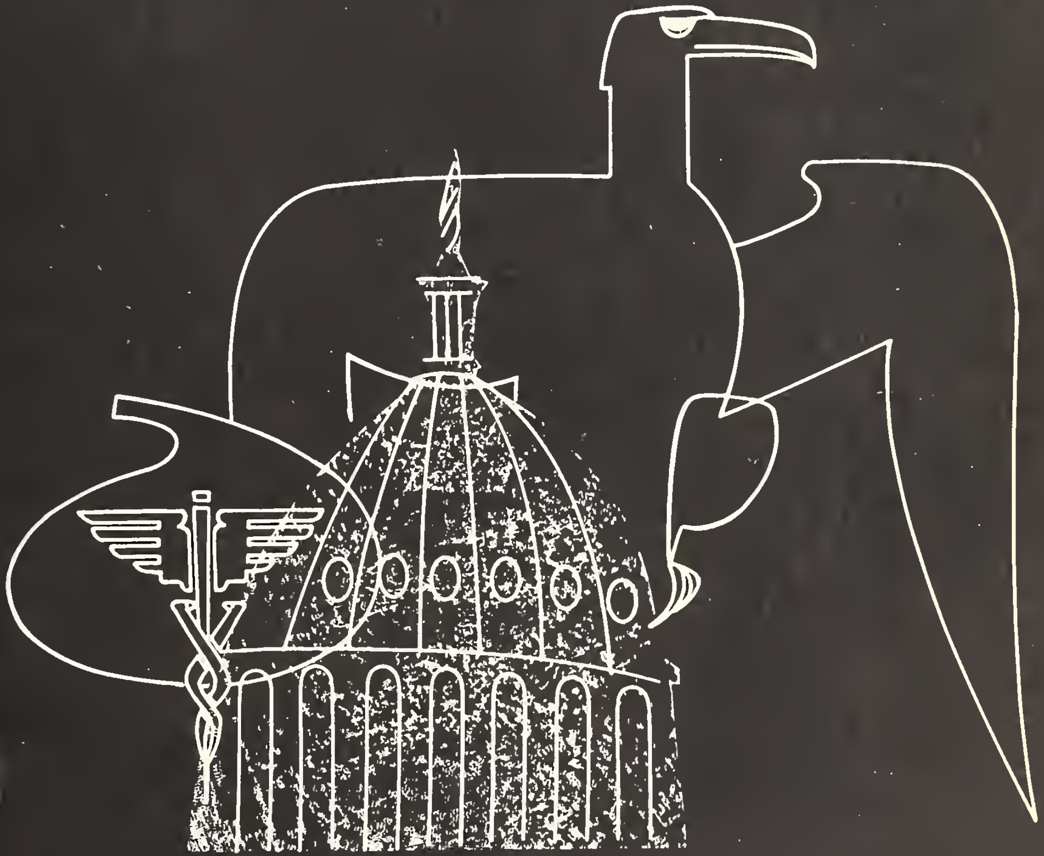
FOURTH

SEMINAR ON SCIENCE AND PUBLIC POLICY FOR SENIOR EXTRAMURAL STAFF

NATIONAL INSTITUTES OF HEALTH
MAY 23-26 1966



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The National Institutes of Health extend appreciation to the staff of the Army Management School for their cooperation and assistance in providing their excellent facilities for this Fourth NIH Seminar on Science and Public Policy.

To Seminar Participants:

The purpose of this seminar on science and public policy is to help us better understand the varied and complex issues, relationships, and influences surrounding scientific programs in the federal government. Our primary concern is with those programs involving biomedical research as supported under the PHS mission; but the pervasive impact of science on politics, and vice versa, is a subject worthy of our appreciation and understanding regardless of the subject context in which it occurs. Consequently, the seminar will explore such seemingly diverse subjects as the Congress, science in American society, and policymaking in the Bureau of the Budget.

Seminar speakers have been selected carefully for their recognized competence and interest in their topic areas. The seminar proceedings are designed for maximum informal interaction, and you are encouraged to put your questions to the guest speakers or before your colleagues for consideration during all sessions. I am certain that you will find this seminar a valuable experience--one which better equips you to serve the public interest as an administrator of federal science programs.

John Sherman

John F. Sherman
Associate Director for
Extramural Programs, NIH

Participants, Fourth NIH Seminar on Science and Public Policy

Morris Belkin
Research Grants Branch
National Institute of Neurological
Diseases and Blindness

Thomas G. Bowery
Assistant Chief
Division of Research Facilities
and Resources

Donald Oken
Chief, Clinical Research
Branch
National Institute of Mental Health

Irving Delappe
Chief, Biochemistry and
Physiology Branch
National Institute of Allergy
and Infectious Diseases

Margaret H. Edwards
Head, Clinical Cancer Training Section
Extramural Programs
National Cancer Institute

Chris Hansen
Chief
Division of Research Services

Victor M. Held
Career Development Review Branch
Physiology Section
Division of Research Grants

Kenneth Hisaoka
Acting Chief, Research Grants
Section
National Institute of Dental Research

Robert L. Ingram
Career, Development Review Branch
Biochemistry & Nutrition
Division of Research Grants

Howard P. Jenerick
Chief, Research Grants Branch
National Institute of
General Medical Sciences

Roman Kulwich
Extramural Endocrinology Program
Director
National Institute of Arthritis
and Metabolic Diseases

William Mayer
Special Consultant to the Chief
Division of Regional Medical
Programs

Gerald F. Meyer
Administrative Officer
Office of Associate Director
for Field Studies
National Cancer Institute

Paul Pearson
Assistant Program Director (Extramural)
Mental Retardation Program
National Institute of Child
Health and Human Development

James W. Pratt
Research Grants Review Branch
Division of Research Grants

Merrill S. Read
Growth and Development Program
National Institute of Child
Health and Human Development

Stephen Schiaffino
Assistant Chief for Referral
Research Grants Review Branch
Division of Research Grants

Julius Segal
Chief, Office of Program Analysis
National Institute of
Mental Health

Irving Simos
Research Grants Review Branch
Psychopharmacology Section
Division of Research Grants

Fred L. Stone
Director
National Institute of General
Medical Sciences

Marjorie P. Wilson
Associate Director for Extramural
Programs
National Library of Medicine

Monday
May 23
7:30
-9:30 pm

A. Science and Public Policy in the American Political Environment.

Charles V. Kidd
Executive Secretary
Fedederal Council for Science and Technology

The relationship of public programs to politically-determined social goals.

The criterion of utility.

The impact of public accountability on policy and processes.

The importance of pluralism in both science and politics.

The question of roles in the determination of public policy: The scientist, the citizen, and the politician.

Tuesday
May 24
9:00
-12:00

B. The Formulation and Integration of Science Policy Within the Executive Branch.

Lee J. Westrate
Office of Management and Organization
Bureau of the Budget

Is a "national" science policy needed or desirable?

Current mechanisms for integration: their operation and effectiveness.

Problems in the coordination of Federal agency programs toward mutual goals.

Tuesday
May 24
2:00
-5:00 pm

C. The Congress and Science Policy.

Herbert Roback
Staff Administrator
Military Operations Subcommittee
House Committee on Government Operations

Congress as an institution.

The increasing concern of Congress with research and development.

Congressional approaches to science policy, compared with other public policy (eg. defense, education, atomic energy).

What are congressional expectations of the scientific community, including the value of scientific lobbies?

Tuesday
May 24
Evening

Informal Small Group Discussion

Wednesday
May 25
9:00
-12:00

D. R&D Programs: The Budget As An Instrument of Choice and Control.

William D. Carey
Executive Assistant Director
Bureau of the Budget

The general budget process.

The budget as:

a tool of program planning,

an instrument of choice among current programs,

a means of measuring program accomplishment.

The desirability of a consolidated science budget.

Federal financial control as it affects the autonomy of academic science.

Wednesday
May 25
2:00
-5:00

E. NIH: Its Role in Biomedical Research and Health Affairs. (Panel)

Philip R. Lee
Assistant Secretary for Health and Scientific Affairs
Department of Health, Education, and Welfare

William Kissick, Deputy Chief
Division of Public Health Methods
Office of the Surgeon General, PHS

Joseph S. Murtaugh, Chief
Office of Program Planning
National Institutes of Health

Wednesday
May 25
Evening

Group Discussion led by Dr. John Sherman, Associate Director for Extramural Programs, NIH.

Thursday
May 26
9:00
-12:00

F. Science and Society: The Broad Implications of Biomedical Research for the Future of Man and His Environment.

Rene Dubos, Professor
Department of Pathology and Bacteriology
Rockefeller University

FOURTH NIH SEMINAR ON SCIENCE AND PUBLIC POLICY
READING LIST

A. SCIENCE AND PUBLIC POLICY IN THE AMERICAN POLITICAL ENVIRONMENT

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* The Scientific Estate, Don K. Price, Cambridge: Harvard University Press, 1965.	
Science, Scientists and Politics, Center for the Study of Democratic Institutions, 1963.	1
"Federal Support of Basic Research," John Verhoogen in Basic Research and National Goals, pp. 267-277.	17
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"Scientists on Tap or on Top? We Are Missing the Real Issues," (letter) L.F. Audrieth in Bulletin of Atomic Scientists, Sept. 1965, pp. 24-25.	33
"The Scientist as Public Administrator," Lewis C. Mainzer, Western Political Quarterly, December 1963, pp. 814-829.	35
"Federal Research and Development Funding and American Higher Education," Leo S. Tonkin, Congressional Record, February 23, 1966, pp. 3605-3608.	51

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"Some Current Problems of Government Science Policy," Harold Orlans, Science, July 2, 1965, pp. 37-40.	71

C. THE CONGRESS AND SCIENCE POLICY

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"Science and Legislative Policy," Herbert Roback, Remarks at the Civil Service Commission Institute for Leaders in Scientific Programs, June 20, 1963.	77
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"Scientific Choice, Basic Science, and Applied Missions," Alvin M. Weinberg, *Basic Research and National Goals*, pp. 279-287. 122

"Research, Development, and the Federal Budget," William D. Carey, Address at the 17th National Conference of the Administration of Research, Sept. 11, 1963. 131

"A Proposal for a Yearly Presidential Report on Science," William D. Carey, *Saturday Review*, Nov. 6, 1965, pp. 57-58. 136

"The Science of Science," Derek J. De Solla Price, *Bulletin of Atomic Scientists*, October 1965, pp. 2-8. 138

* *The Politics of the Budgetary Process*, Aaron Wildavsky. Boston: Little-Brown, 1964.

E. NIH: ITS ROLE IN BIOMEDICAL RESEARCH AND HEALTH AFFAIRS

"Onward the Management of Science: The Wooldridge Report," Joseph D. Cooper, *Science*, June 11, 1965, pp. 1433-1439. 145

"National Planning for Medical Research," Philip Handler, *Science*, June 25, 1965, pp. 1688-1692. 152

F. SCIENCE AND SOCIETY: THE BROAD IMPLICATIONS OF BIOMEDICAL RESEARCH FOR THE FUTURE OF MAN AND HIS ENVIRONMENT

"Biopolitics: Science, Ethics, and Public Policy," Lynton K. Caldwell, *The Yale Review*, October 1964, pp. 1-16. 157

"Science and Man's Nature," Rene Dubos, *Daedalus*, Winter 1965. 173

* Distributed separately

NIH wishes to acknowledge the cooperation of the authors and publications listed in the preceding index for their permission to reprint the articles and papers in the following section.

SCIENCE, SCIENTISTS, AND POLITICS *is made up of some of the papers presented at a conference on the role and responsibilities of science executives in the service of government. The conference, which was held in Santa Barbara, was sponsored by the Center in cooperation with the Twelfth Region of the United States Civil Service Commission.* ROBERT M. HUTCHINS *is President of the Fund for the Republic. His career as President and Chancellor of the University of Chicago provided first-hand experience with the subject of this paper.* SCOTT BUCHANAN, *Consultant to the Center, was Dean of St. John's College. His books include* Poetry and Mathematics, *reissued in paper-back last year.* DONALD N. MICHAEL, *author of the Center pamphlet,* Cybernation: The Silent Conquest, *is Director of the Peace Research Institute in Washington, D. C.* CHALMERS SHERWIN *is Vice President and General Manager of the Laboratories Division of Aerospace Corporation in Los Angeles.* JAMES REAL, *management consultant for government and industry, is co-author of the newly published Center book,* The Abolition of War. LYNN WHITE, JR., *former President of Mills College, is Professor of History at the University of California at Los Angeles.*

Robert M. Hutchins

I do not know much about science, but I know a lot about scientists. Though I do not know much about professional politics, I know a lot about academic politics—and that is the worst kind. Woodrow Wilson said that Washington was a snap after Princeton. Not only is academic politics the worst kind of politics, but scientists are the worst kind of academic politicians.

I wish at the outset to repudiate C. P. Snow, who intimates in one of his books that scientists should be entrusted with the world because they are a little bit better than other people. My view, based on long and painful observation, is that professors are somewhat worse than other people, and that scientists are somewhat worse than other professors. Let me demonstrate that these propositions are self-evidently true.

The foundation of morality in our society is a desire to protect one's reputation. A professor's reputation depends entirely upon his books and his articles in learned journals. The narrower the field in which a man must tell the truth, the wider is the area in which he is free to lie. This is one of the advantages of specialization. C. P. Snow was right about the morality of the man of science within his profession. There have been very few scientific frauds. This is because a scientist would be a fool to commit a scientific fraud when he can commit frauds every day on his wife, his associates, the president of his university, and the grocer. Administrators, politicians (not campaigning), and butchers are all likely to be more virtuous than professors, not because they want to be, but because they have to be.

One odd confirmatory fact is that those whose business it is to lie, such as advertising men, are often scrupulously honest in their private lives. For example, Senator William Benton, founder of the firm of Benton and Bowles, used to say that he had to be honest on Madison Avenue because if he wasn't word would get around that Benton was a crook and he would be ruined. When he retired from the advertising business he became vice president of the University of Chicago, whereupon he was prompted to say, "Look at these professors. What harm would it do them if word got around that they were crooks? They are all on permanent tenure!"

The general moral tone of academic life was once handsomely demonstrated at a University of Chicago faculty meeting. It was a solemn occasion. Two hundred full professors had assembled to discuss whether the bachelor's degree should be relocated at the end of the sophomore year, giving it and other degrees a meaning they had never had before. The faculty debated this proposition for two hours without ever mentioning education. The whole discourse concerned the effect of the proposed change on public relations and revenue. Mr. Benton, fresh from Madison Avenue, stormed out of the assembly shouting, "This is the most sordid meeting I ever attended in my life!"

There are many examples of this kind of professional morality. The chairman of a scientific department of the University of Chicago marched into my office one day and told me that we could not appoint one of the world's leading theoretical astronomers because he was an Indian, and black. Another faculty member, a great American sociologist, who was president of the American Statistical Association and president of the American Sociological Association, once informed me that it would be impossible to appoint a Negro to the faculty because all the graduate students would leave. We appointed the Negro anyway. As far as I know, no graduate students left.

The University of Chicago medical school violently resisted admitting Negro students. Negroes and Jews who had noncommittal names and were not otherwise visible to the naked eye were detected in photographs required with applications for admission. It took an executive order from my office to eliminate this requirement. Fortunately the medical school did not know that under the statutes of the University I had no power to issue such an order.

It is clear that the behavior of professors is questionable at best. Scientists are worse than other professors because they have special problems. One of these is that their productive lives often end at thirty-five. I knew an astronomer who was contributing to the international journals at the age of eleven. Compare that with the difficulty of contributing at a similar age to an international journal on, let us say, Greek law. A scientist has a limited education. He labors on the topic of his dissertation, wins the Nobel prize by the time he is thirty-five, and suddenly has nothing to do. He has no general ideas, and while he was pursuing his specialization science has gone past him. He has no alternative but to spend the rest of his life making a nuisance of himself.

Scientists are the victims of an education and a way of academic life created by their misinterpreters and propagandists. These misinterpreters have propagandized an entirely inconsecutive chain of consecutive propositions: The pursuit of truth, they say, is the collection of facts. Facts can be experimentally verified. Thus, the only method of seeking truth is the scientific method. The only knowledge is scientific knowledge, and anything else is guesswork or superstition. So Lord Rutherford could say to Samuel Alexander, the great English philosopher, "What is it that you have been saying all your life, Alexander? Hot air. Nothing but hot air."

A recollection I shall always cherish of one of our leading mathematicians, now a professor at Chicago, affords a stunning example of the frame of mind the propagandists have created. He came to Chicago as a graduate student. Toward the close of his first year I asked the chairman of the mathematics department how the boy was doing. "Oh, Mr. Hutchins," he said, "he's a fine mathematician, but I'm sorry to have to tell you, he's crazy." I said, "What do you mean 'crazy'? How does he evidence this unfortunate condition?" And the professor responded, "He's interested in philosophy!"

The misinterpreters' and propagandists' doctrine has paralyzing educational repercussions. According to its tenets, education consists in cramming the student with facts. There is not enough time to stuff in all the facts. Therefore, facts outside a narrow area of specialization must be excluded. One of our Consultants to the Center has described the education in science in the state university from which he graduated as two years of German, two years of military training, and all the rest mathematics, physics, and chemistry.

Seduced by the fact formula, the medical school at the University of Chicago set out on a perfectly sincere, although somewhat misguided, campaign against liberal education. There are countless facts in medicine. A medical school must fill its students with these facts or they will fall behind. This meant that there was no time to teach anything else. The medical school strongly recommended that the whole freshman and sophomore years be abolished—the junior and senior years had already gone—and that the entire curriculum be devoted to science and medicine. I can conscientiously say that any senior in the University of Chicago medical school knew more facts about medicine than any professor in a German university.

The consequences of this line of educational endeavor are clear enough. Everybody specializes. There can be no academic community because scientists cannot talk to one another. The chairman of the anatomy department of the University of Chicago brought this home to me once when we were discussing the great biological symposium that had been held to celebrate the University's fiftieth anniversary. I said, "Tell me, how was it?" He said, "I didn't go." When I asked why not, he replied, "Well, there weren't any papers in my field." Scientists cannot talk to anyone else because there isn't anyone else worth talking to. Hence, university life offers no remedy for the defects of their education.

The propagandists and misinterpreters of science have set the tone for the whole learned world in the United States. Their slogan is, "If you can't count it, it doesn't count." The influence of this slogan is felt in literature, philosophy, languages, and of course in the social sciences. The most striking feature of social science today is the total absence of theory. Its greatest modern achievement is the public opinion poll. Social scientists can count, but cannot comprehend.

Those who live their lives without theory are technicians, or mechanics. As a result there is no significant contemporary social science. Politics is viewed as power because power can be observed and measured. Power is something real. Therefore, using the misinterpreters' logic, it is *all* that is real about politics or political science. The most characteristic book title in social science in the past thirty years is *Politics: Who Gets What, When, How.*

In spite of the misinterpreters' nonsense, science contains elements of sense. Serious scientists know that science is just one very important way of looking at the world. When scientists are actually doing science they are caught in a great tradition. They know they are not simply collecting facts or conducting random experiments. No serious scientist believes that if a million monkeys were put down at a million typewriters one of them would eventually turn out *Hamlet.* Nor does he think the scientific method is the only method. Scientists do not use the scientific method outside of science.

How the propagandists and misinterpreters of science have managed to take over all the academic virtues and label them "scientific" escapes me. I ran across a fascinating study of the scientific attitude by a professor of education. This learned gentleman had written to sixteen eminent scientists and asked them what characterized the scientific attitude. These were the replies:

CHEMIST: *Openmindedness* . . . PHYSIOLOGIST: *Intellectual honesty* . . . BOTANIST: *Openmindedness* . . . ZOOLOGIST: *Observation, inquisitiveness, perseverance and industry, objectivity and critical independent reflection* . . . PHYSICIST: *Objectivity* . . . SOCIOLOGIST: *Objectivity* . . . MICROBIOLOGIST: *Respect observation* . . . MATHEMATICIAN: *Openmindedness* . . . ANTHROPOLOGIST: *Openmindedness* . . . CHEMIST: *Practiced willingness to label conclusions tentative until supported by reproducible or confirmed data* . . . AGRICULTURIST: *Desire to tolerantly explore ideas* . . . MATHEMATICIAN: *An open mind* . . . PHYSICIST: *A will to know the truth* . . . CHEMIST: *Insistence on critical examination* . . . DIRECTOR OF EDUCATIONAL RESEARCH: *Intellectual curiosity* . . . PSYCHOLOGIST: *An inquiring mind.*

Obviously this study shows that science has a corner on all the rational processes of thought.

But there is not an honest scholar in any field who would not insist on being openminded, honest, and objective, and on considering all the evidence before he reached a conclusion. You can hear Thomas Aquinas laughing.

The propagandists of science say, "Sure, but fellows like Thomas Aquinas had commitments. They all had philosophies and principles that distorted their thinking. Scientists haven't any." The answer to this is that everybody has a metaphysics. Every scientist, for example, has a commitment to the reality of the external world. The distortion comes when the metaphysics is denied instead of being recognized and made as rational as possible.

Understanding science is an indispensable part of a liberal education. To demonstrate my sincerity, I point out that at the University of Chicago one whole half of the first two years of every student's education was natural science. St. John's College, with which I also had something to do, is the only college in the United States that requires four years in the laboratory for every student. An education without science is no education at all. The limitations and possibilities of science cannot be understood without scientific training, and our very existence depends on comprehending these limits and possibilities.

We do not know what science is, and partly as a result we do not know what politics is. Mr. C. P. Snow is wrong about the two cultures. There is only one, and it is pseudo-scientific.

The leading phenomena of our time exhibit a curiously ambiguous character. Technology may blow us up, or it may usher in the paradise of which man has been dreaming ever since Adam and Eve got kicked out of the first one. Bureaucracy may stifle democracy or be the backbone of democratic government. Nationalism may disrupt the world or prove to be the necessary precondition of a world community.

Unfortunately these ambiguities do not lend themselves to scientific procedure. Our essential problem is what kind of people we want to be and what kind of world we want to have. Such questions cannot be solved by experiment and observation. But if we know what justice is, which is not a scientific matter, science and many other disciplines may help us get it.

The problems resulting from these ambiguities are not going to be solved by men of fractional or pseudo-culture. The solution depends on moral and intellectual virtues rather than on specialized knowledge. It is a humbling thought to recall that 25 per cent of the SS guards in Nazi Germany were holders of the doctor's degree.

The solution of these problems must lie in the reorganization of American education and in the redefinition of its purposes. A liberal education, including scientific education, must be established for all, and true intellectual communities must be built where men may overcome the limitations of their fractional cultures. This would require a drastic change in what the nation expects of American education, and an equally drastic alteration in the habits of academic people. I think it will be agreed that this cataclysm is not likely to occur in the lifetime of the youngest person reading this.

The immediate program, then, has to be something else. It must be an attempt to build intellectual communities outside the American educational system and to form widespread connections among the intellectual workers, using these communities as points of interconnection. The hope for the immediate future, as far as we have one, must rest in our capacity to communicate with the adult population. For one thing, unless we do, the rising generation may not have a chance to rise.

It is in centers like the Center for the Study of Democratic Institutions and in the multiplication of meetings like the one that produced these papers that we might get some help with the development of a real culture, and a real understanding of kinds of knowledge and the limits and potential of each kind. The radiation from these points might light the path to a just community for ourselves and for the world.

Scott Buchanan

The implication in discussing the nature of science and technology is that a distinction should be made between science and technology. Such a distinction is almost wholly unrecognized in our scientific cultural environment. In a recent seminar in which I participated the question of the difference between science and technology came up and the answer was: "There isn't any. We no longer separate them." This is a shocking statement. It is sobering to think that there is no possibility of distinction.

C. P. Snow has said that scientists and technologists have become soldiers. They are not working for themselves: they accept orders from others. They are not able to take responsibility for their own strategic judgments in science, to say nothing of the uses to which their work will be put. Whether the decisions are being made on the scientific or the technical level, scientists are not making them.

President Eisenhower in his farewell speech pointed out two things that needed to be watched: the hook-up among the military, the scientific community, and the industrial community, and the hook-up between the scientist and the administrator. We may have heard more about the scientist-soldier than about the scientist-manager, but the latter is equally threatening to the political community.

When a scientist is a soldier, he is subject to direction and is a means to an end established by someone else. When he is a manager, he sets the goals and directs other people. But this may not be as deep a paradox as it first appears. Both as a soldier and as a manager the scientist is involved in practice, in practical activity. He is work-g in what a traditional philosopher would call the "realm of practical reason." Usefulness is the standard by which he judges his work. Thus it is difficult to distinguish between science and technology because part of the meaning has gone out of science. The scientist has diminished not because he has become irrational, unreasonable, or arbitrary but because he has become a technologist.

Limiting science to the practical realm is comparatively new. Science was not born in the fifteenth or sixteenth century. The word "science" has had a long usage —about 3000 years—and until modern times its meaning contained concern about truth, pursued by speculative or theoretical reasoning rather than practical reasoning. These too are diminished words. Speculation has become something done on the stock market, and theoretical means "academic" to the general public. To the technical scientist theory is simply a means to an end. But there are some slightly old-fashioned scientists around who feel that the essential nature of science is not involved with practical reason. They say the scientist's work is to discover the truth, formulate it, and make it a matter of public as well as professional knowledge.

In Thorstein Veblen's striking phrase, "A scientist is addicted to the practice of idle curiosity." This defiant definition states in a humorous way a high dogma about what science is. This is the origin of the popular notion that the scientist is neutral on questions of utility or on the affairs of practical life. Idle curiosity means that the scientist is concerned only with truth. The results of the search for truth may be used for good or evil, but it is now said, even by scientists, that judgments about their use cannot be made by science.

If the scientist's concern is truth, it is his responsibility to be sure that science is not misused so that something false comes out of it. The burden of maintaining the activity of discovery implies a responsibility for academic freedom, but few scientists have defended academic freedom in this country though it has been in danger for the last generation. Perhaps it is because most scientists do not distinguish science from technology. Academic freedom may not be essential to questions of application and use. There is not much point in defending it if truth is not the object. If there is any absolute reason for academic freedom, it is that the search for knowledge of truth is an activity of human beings essential to everything else they do. The heaviest responsibility of the scientist to society may be to refuse to make himself useful.

Several kinds of sharply different judgments are to be made about the whole range of science and technology. The scientist, as a man concerned about the truth, makes one essential judgment about his findings: whether they are true or false. The technician, as an original inventor or as an adapter of something already discovered, makes a judgment of usefulness or fitness. He decides whether it works, and need not judge whether it is good or bad in any other sense. Business or industrial interests make different judgments from those of the scientist or technologist, which partly explains the difficulty of communication between the laboratory and the industrial manager. A much more general judgment about the utility, validity, and desirability of scientific work is made by society and imposed by social pressures.

But there is something missing in this series of judgments. The purposes of science may be considered by the scientist as a professional man. "Profession" as it was once understood meant more than a specialty. Universities were founded in Europe to educate and certify those who aspired to the professions, and the training included more than science. Students were taught the liberal arts, and achieved a realization of a larger theoretical, speculative body of knowledge in which the sciences are placed. From this point of view it is possible for a scientist to stand before the community and say "yes" or "no" to the alternative applications of science. But we no longer understand what the liberal arts are. We call them philosophy, but philosophers have shrunk into departmental academicians. The professional man, in fact the whole society, does not have a good philosophical background, and as a result there is a kind of judgment that is not being made. It is the only kind of judgment that could distinguish between science and technology.

Although medicine has lost a great deal of the philosophical professional integrity that was once expressed for an earlier time in the Hippocratic oath, physicians as individuals and as a group still make professional judgments. They do not prescribe poisons indiscriminately; they do not let commercial pharmacists dispense certain drugs without prescription; they judge malpractice. Although these judgments seem to belong to ethics, they are not primarily ethical. They are based on the professional theoretical knowledge of the physician. If the natural and social sciences wish to become professional, they need to discover and formulate such judgments both for themselves and for society. But in order to do that they will have to become philosophical enough to distinguish between truth and workability.

Donald N. Michael

Anthropologists and historians tell us that a crucial juncture in the life of a culture occurs when the assurance that it has gained from an unchallenged world view of values, goals, and logic confronts the unchallenged world view of another culture. It is not easy for men to change their view of the world, for it is part of their view of themselves. The challenge of other values threatens all that has given them comfort and support. It takes strong men and felicitous circumstances for a society to ride out the storm of contact with another culture and learn and grow anew.

It is by no means certain that this will happen. Some people are shattered by new experiences; so are some cultures. As segments of society splinter and converge, new institutions and new modes of thinking are generated. Some societies blossom in their revised form; others die.

Today we are faced with such a cultural crisis. The problems of making suitable policies for scientific work in the government arise chiefly from a profound cultural conflict. This conflict is the three-way confrontation among the scientific community, the non-scientific political governmental community, and the general public.

What is meant here by an adequate policy for federal science must be made clear at the outset. Such a policy would reconcile the needs of science and technology with the needs of the rest of society. Policy now springs from resolving disputes for priority among various projects. It is made in many places, from the Pentagon to the Department of Agriculture, as well as in those offices assigned part of the policy-making task. But nowhere do the social implications of science have a basic part in the formulation of policy.

Today, science and technology are not neutral. Not only does their development require vast social and human resources, but they are pursued because their powers for enhancing or degrading humanity are recognized. This non-neutrality demands an explicit relating of science and technology to the needs and processes of society. This relationship should be the foundation of federal science policy.

The one consensus among the three cultures—the scientific community, the non-scientific political community, and the public—is that the task of government is to serve the general public. There is no such agreement about the relationship of science to government and to the general public. There is no set of values mutually subscribed to by the three cultures that defines the proper purposes of science and technology and thereby the appropriate restraints and supports needed to fulfill those purposes. Nor is it clear that such a set of values can be deliberately produced. Values do not derive solely from rational considerations. They are historical products of emotion and plain accident as much as, or more than, reason. This is one weakness in the thesis that the scientific method by itself can solve society's problems.

Within each of the three cultures are men and institutions with different viewpoints and different goals. These dissimilarities are crucial. Some of them derive largely from training; some are induced by the preconceptions that each group has about the other two and about itself. Two of the three are contending for the power to insure that their particular values will prevail: the science community and the non-science governmental community. The general public has essentially no power.

The *science community* is represented at its upper levels by two types of scientists. The "traditional" type considers government to be synonymous with mediocrity and irrationality. These men feel that science must be left free to pursue its own ways. Their attitudes toward the rest of society are frequently ambivalent. They avoid involvement in social questions. Some of them perceive society as subject to, if not already operating along, logical lines. Others consider society as incorrigibly irrational and therefore unrelated to them. They are seldom asked to consider the social implications of their actions. By attending to their work, advising on the technical merits of this or that proposal, they can maintain the comfortable delusion that science can still be pursued without thought of the social consequences. Frequently they work for the university or for big industry, advancing the favorite programs of their employers.

Then there is the new breed of scientist around high Washington conference tables—the science entrepreneur, the "political" scientist. These men want to manage th bureaucracy to the extent necessary to make it behave the way they think it should. They have a sense of politcal technique, and they enjoy and seek power. Like the traditionalists, they feel that science is theirs, that no one else has the right to tamper with it. It is they who should decide which projects deserve emphasis. They believe a good dose of science would fix society fine, as C. P. Snow has so frequently tried to demonstrate. There are wise and modest men with social imagination in this subculture, but frequently the powerful members of this group are self-assured to the point of arrogance about their own abilities, about the over-riding rightness of scientific values and methods, and about the validity of their view of how society operates and what it needs.

The science entrepreneurs are supported by and in turn support big business, big publicity, big military, sometimes big academia and parts of big government. They are both the captives and the kings of these powerful coalitions — kings for obvious reasons, captives because in reaping the benefits of affiliation they capitulate in some degree to the operating principles of these institutions. They have climbed to power through conservative hierarchies and tend to hold conservative values. The infusion of émigrés from the disciplined institutions of Europe seems, in general, not to have been a liberalizing influence. The more powerful the "political" scientist gets, the more omnipresent he is at major deliberations on science policy.

The *non-scientific community* in Congress and the bureaucracies regards itself as the bones, meat, and brains of government and society. They resent the "woolly-headed" scientist who may be trying to change their ways or implying that these ways are inadequate. They are not about to be displaced by a new attitude or a new kind of knowledge. Scientific expertise is respected, but the political and social naïveté that is supposed to accompany it is regarded with disdain. A general feeling exists among these "non-scientists" that science must be controlled. Usurpation of power is feared, partly because of a conviction that science somehow cannot be stopped.

These men consider society a non-rational environment. They see the political process as subtle and changing, responsive to many pressures of which science is only one, and by no means the most important. They view science as a means, not as an end. But they are confused about means and ends in general, as well as about the implications of science, and have no clear view of the proper role of scientists in formulating policy.

These two cultures between them decide on national science programs. They are in deep conflict within and between themselves. There are great political and ethical splinterings in the science community alone. The entrepreneurs claim to speak for science, but speak only for their faction. The traditionalists are fearful and envious of the "political" scientists, upon whom they must depend for their survival, especially if they hope for accomplishment in fields requiring expensive equipment or team research. Both groups are dissatisfied with the workings of government.

Given this clash of cultures, how can a valid basis be found for policy-making in federal science? We must discover a common ground from which science and technology can be intelligently directed. We must be able to evaluate the social consequences of scientific innovation. We need to plan our economics to assure the effective and humane introduction of modern technologies. We must equip government to meet new regulatory and managerial tasks. It is not clear that these responsibilities can be met by any traditional form of government; nor is it certain that democracy can be preserved in doing so. What is clear is that we cannot continue to bumble along.

Already we are in desperate trouble over nuclear weapons. We are about to be overwhelmed by that terrible blessing of medical technology, overpopulation. The social implications of biological and psycho-pharmacological engineering are already evident. Cybernation is causing serious problems. What is more, our environment is being changed in ways no cybernetical system can cope with indefinitely. It must respond to a tremendous and growing range of information at increasing speed and with increasing accuracy. Instability of the system is the inevitable result.

In spite of these menacing developments we remain unable to forecast the social consequences of technology. This is partly because of the limited vision of both the non-scientists and the scientists. The first group does not have sufficient knowledge of technology to sense the potentialities of new developments and therefore cannot predict their social impact, and they are too preoccupied with conventional assessments of political issues and impacts. The second group is aware of the technological possibilities but is not sufficiently sensitive to their social implications. Some of the scientists care only about the success of their favorite projects. Some apply to these problems a personal pseudo-sociology made useless by its arrogance or naïveté. And still others dodge responsibility by arguing that technology itself is neither good nor bad, that its virtues are determined by its uses.

Another reason why the social repercussions of science are difficult to forecast is that we have too little understanding of the social processes. This limitation has been fostered by the disinclination of the natural scientist and the government operator to stimulate work in the social sciences. The bureaucrat feels threatened by the possibility that formalized knowledge will replace "experience" and "political know-how." Furthermore, the social sciences might demonstrate that the products of technology, or even science itself, need social control. This is an unhappy prospect for those scientists who are feeling for the first time the satisfactions of wielding power.

Since the consequences of scientific and technological developments are not fully predictable, it would seem impossible to establish priorities for individual projects on any sensible basis. Yet the forces of technological advance compel some kind of choice. Creative talent is a scarce resource, and the availability of money is a political, if not a real, limitation. "Political" scientists push their preferences vigorously, and the very existence of large programs influences selections in the absence of better criteria. Priority decisions today depend on political and economic pressures, personalities, and public relations.

The public relations juggernaut, in particular, imposes a crippling distortion on science and on those who would make scientific policy. From the laboratory to the launching pad science and technology are harried by promises about "product superiority" and the glamour of "breakthroughs." Commitments are quickly publicized and then science is pressed to maintain the "reality" of the commitments. The natural failures of science and the natural limits of accomplishment are covered by an ever-deepening layer of misrepresentation, deviousness, and downright lies. So pervasive becomes the aura of untruth that it is hard for anyone, from the man in the laboratory to the public, to know where reality lies.

A cliché of our political folklore is that somehow the *public* will make everything right. In its wisdom it will judge between the contending power groups, evaluate technologies, establish a scale for priorities. But the public, the third culture, hardly knows what is happening. Understanding or judging the conflicts and compromises now occurring between science and government is far beyond its capacity. The public is caught between a publicity-induced fantasy world where science knows all the answers and a frustrating actuality which it does not realize is caused at least in part by the inadequate or incorrect use of science and technology. The frustrations are blamed on someone else: Russia, the government, perhaps the intellectuals, seldom on science. The public still believes in the mad scientist working on bombs, or in the humble scientist laboring over polio vaccine. The member of government, civil servant or politician, is perceived no more realistically.

Rather than becoming able to resolve the problems of science policy, the public is likely to become increasingly alienated both from government and from science. As with many other groups in the past that have met cultures somehow superior to their own, the public may withdraw from the challenge of "adjusting up" to the new priests and the new power. How, in fact, can the ordinary citizen adjust up to a computer-run society and classified questions of life and death?

One segment of the public will not surrender without protest. This is the group of articulate, concerned laymen who are not solely scientists, politicians, or civil servants and who worry about the arms race, overpopulation, the ascendancy of the "political" scientist, and the inadequacy of non-scientific bureaucracies. These people might be the moderators, the synthesists, for a new culture. They do not have the trained incapacities of those solely immersed in the two contending cultures, and they do have perspective that the general public lacks. But these very characteristics may deny them the opportunity. The day of the technical specialist grows ever brighter. The scientist will not freely yield his newly gained power, nor will the government worker relinquish his long-held dominion. Neither is likely to give ground to a non-specialist who cannot build bombs or tread bureaucratic water, or otherwise play according to the rules of science and government.

The character of the coming generation of scientists is changing. The attributes attractive to laboratory directors interested in team-work are bringing a new personality into science. The old-guard traditionalists may be on the way out. Those who succeed will be those who are good at working with – or subverting – the non-scientific bureaucracy. Will these men be good scientists? This is not the important question. The real concern is for whom they will speak, and for what ends.

The problem in trying to resolve the ambitions of the two power cultures is that neither group has a clear view of what it wants in the way of policy for governmental science. As long as there is no community of values to guide judgment, basic policy decisions cannot be made, much less decisions on specific priorities for specific projects. Yet crises are arising on every hand. The evolution of a consensus cannot be awaited. If this society does not learn how to assimilate the changes that confront it, it will not survive.

Chalmers Sherwin

Science and technology are the key to the future, the key to power, and the key to the solution of the problems we face today. They alone will not save us, but if we seek to untangle our problems without them, we are lost.

In the last thirty years the increasing sophistication of the physical and biological sciences has exhibited the properties of a true revolution. It has radically altered the social organization within which it grew. It emerged in less than one working generation, and the suddenness of it caught all of us off balance. People still believe that science can be handled by the techniques and devices that it has itself made obsolete, or that if the problems it has brought are ignored they will vanish.

A common modern complaint is that while government has spread like an octopus, our problems have grown worse. It follows that the cure for our ills is less government. But government did not bloom spontaneously. It grew in response to the scientific revolution. As men have invented more gadgets and uncovered more knowledge about the world, an enormous expansion of government has been necessary, both to protect the public interest and to foster further scientific advance.

In 1800 the government of the United States played a modest role. It had an army, a postal department, a tax on whiskey, and some import duties; the Department of State kept track of the world. That was about it. But by 1830 railroad and steamboat traffic began to grow, and, to regulate it in the public interest, so did federal power. Later, internal combustion engines were invented, more was discovered about aeronautical science, and suddenly airways had to be regulated. Telegraph, radio, and television each generated complicated governmental problems. Modern chemistry and pharmaceuticals brought into being the whole field of food and drug control.

The economic disaster of agricultural overproduction, a triumph of applied science, is a prime example of the difficulties that technology has handed to government. The farm problem really began in 1862 when land-grant colleges were founded with federal support. By 1900 science was being applied to agriculture on a big scale, and by 1920 food production was beginning to be excessive. Hybrids, modern machinery, new methods of food processing, and new types of fertilizers were developed, and all at once America was producing too much food. Science and technology caused the surplus, but the federal government had to try to cope with it. Its efforts to do so, plus its efforts to make agriculture still more efficient, have spawned a giant bureaucratic structure.

The biggest surge of all in government growth was caused by the exploration of the atom. In 1939, when science suddenly found a major key to the secrets, no one but the government could afford to exploit it. Science has not stopped finding keys—those to space, for example – and the job of the federal government has not stopped getting bigger. Atomic and space research are unsuitable for private exploitation, not only because the government alone can afford the massive costs, but also because the results require governmental control.

The expansion of government suggests support for the idea that government should control science and technology. The feeling that modern knowledge and power must somehow be turned to the public good has currency. Even those interested only in the progress of science want government to help sustain its advance. Whether government's job is constraining science to serve the public interest or promoting the scientific front, or both, it must understand the phenomenon with which it is dealing.

Unfortunately, the people running government often do not understand science and technology. Despite some notable exceptions, scientific ignoramuses usually handle scientific decisions. The serious technical questions, such as how atomic energy and military space operations can be controlled, will remain unanswered until this basic difficulty is somehow solved.

Government managers of science and technology often do not know their business, partly because, as C. P. Snow argues, our educational system is no longer geared to the source of our power. Our power now rests on science, but we let those who administer and govern remain incompetent in the substantive knowledge of the area.

The revolution in science can be distinguished from the industrial revolution by the fact that a high school undergraduate can understand the principles of the latter. The steam engine, a railroad train, and, with a little more effort, even an electrical generator are within his grasp, but he gets lost in modern biochemistry, electronics, and nuclear physics. Mastery of this new knowledge is not quickly won. The subtleties of modern research and development, or even of technical production, are not easily learned late in life. But a manager *must* know the substance behind the problems he handles if he is to be effective. It is increasingly true that critical evaluation of substantive technical details is the very heart of policy decisions. The era of classical administrative formulation, "You name it, I'll manage it," is past. Today, few people except professional scientists have the technical sophistication necessary to make many of the crucial decisions affecting both science and society.

Using scientists in government seems an obvious answer to the dilemma of management. But creative scientists and engineers are usually outside government. Most creative physical scientists are in universities, which is remarkable considering the salary structure. Private industry employs a big proportion of our scientific talent, which means that these scientists are under pressure to serve industrial aims and their loyalties are often diverted from the public interest.

Part of the reason why the scientific community is clustered outside government has been the mismanagement of science by the military. Military power must now be considered primarily in terms of science and technology. Yet military organization and education have not changed to fit the new facts. Obviously the military will need more and more scientifically mature personnel and fewer squadron leaders, but it continues to train squadron leaders. What is more, up to now it has had a negative approach to its selection of scientific management. Processes used to select a good man to run a submarine are applied, despite their inappropriateness, to selecting a man to run a laboratory or to choose between two complex weapons systems. Good scientific managers are automatically weeded out, and poor ones promoted

Unfortunately, the traditional military organizational structure tends to be inimical to the promotion of scientific progress. It was designed to produce specialists in violence. Now suddenly the most critical task is the selection of highly technical weapons systems—a function for which the military structure is not particularly suited.

But scientists outside government still try to influence matters from the edges by pulling strings and poking their fingers into the wheels. They give generalized advice, but the problems are specific. Someone must choose, for instance, between spending $500 million to make better re-entry vehicles for missiles or spending $500 million to build a completely different missile with a different basing system, and these decisions must be lived with. The kibitzing scientist, not responsible for the consequences of his advice, is at best of limited usefulness; at worst, dangerous.

Responsibility and scientific competence must somehow be brought together if government is to serve the public interest and if the right decisions are to be made to advance the intricate giant that science has become. Having the top ranks of government heavily staffed with people trained in science, who really know how to handle scientific problems, is a solution apparently not available to this country. Obviously it is being tried in Russia.

In the United States the government, lacking scientific expertise, farms out its scientific problems to industry. The ordinary profit-making company has a very limited sense of public responsibility. It may be effective in production and capable of top-notch research and development, but its interests often — and necessarily — diverge from the public interest. There is a tendency to let the government finance the long shots but to seize promising developments and exploit them with company money. Industry naturally tries to exploit governmental support for private gain (within legal limits) and steers the short course of its own health and well-being. If a company is to survive in this quasi-capitalist society, it must look out for itself first. Because of this inevitable self-interest, industry must not be allowed to become the arbiter of national science policy by default.

One promising scheme for handling science and technology in the public interest has been the non-profit organization, or, as they prefer to be called, the public trust organization. The government first used the non-profit device in about 1820, when it gave a contract to the Franklin Institute in Philadelphia to find out what made steam boilers explode. In the last thirty or forty years there has been a proliferation of non-profit organizations which have been extremely effective in basic research, applied research, and even production. A number of these are run by universities, such as the Argonne Laboratories of the University of Chicago, M.I.T.'s Lincoln Laboratory, and the University of California's two weapons research labs and its operation at Los Alamos. There are also private non-profit companies like RAND, System Development Corporation, and Aerospace Corporation.

The main advantage of these organizational inventions is that they are insulated from bureaucratic meddling. They work on governmental problems outside the governmental structure. They typically have a broad charter in which their responsibilities are general, their budgetary restraints non-specific, and monitorship of their operation reasonable. They permit a freer use of scientific talent. They break through the unrealistic ceilings set by government on the salaries of scientists and allow the public service to compete on an even economic footing with private industry. Most important, they are able to maintain an atmosphere congenial to the scientific community.

This kind of freedom is necessary for scientific accomplishment, and the method has proved itself. In terms of technological productivity the non-profit groups have been extremely successful, particularly with the AEC. But the freedom on which their success is based is achieved by a delegation of power from government, and even though they have strong internal commitments to the public interest, and their actions usually serve that interest well, they do not literally represent government.

What is needed is an invention *inside* government equivalent to these non-profit corporations. Within government a delegation of authority and responsibility could be made to large self-contained units. The liberty necessary for a benign environment for science could be preserved, and creative scientists might be lured into government service. Yet the power to direct the course of science and weigh its consequences in terms of the public welfare would not be relinquished. The AEC system, an experiment in governmental management of science and technology, is a significant step in the right direction.

A new and better marriage must be made between governmental responsibility and scientific capability if the full promise of science is to be realized and its perils escaped.

James Real

Almost 80 per cent of all research and development monies are furnished by government, of which all but a small fraction are directed at prompt application to the technologies of warfare and its endless supporting apparatus.

It is unlikely that we shall ever hear again such lines as were delivered in 1958 by a distinguished Nobel Laureate physicist to an assembly of his colleagues. "The scientist," he insisted, "has no idea what disposition will be made of his work. There is usually at least a two-year lag between his discoveries and their unpredictable applications." The Laureate went on to spin out this thesis of disassociation, even though everyone in the hall was intimately aware of the hundreds of laboratories and plants created for and totally supported by government, populated by tens of thousands of physical scientists working cheek to jowl with lesser folk to achieve specific and immediate technological ends.

As incredible as this posture was in 1958, it is now even more absurd. Today there are fourth and fifth generations of scientists who have never worked on anything but weaponry and who view their careers as lifelong. They are permanently dedicated to the invention and construction of what may appear to be a succession of weapons systems stretching through foreseeable time. In a real sense, these men are institutionalized: captive to their narrow specialties and to the paymaster, the grant, and the contract.

The military, who are the ultimate appliers of the laboratory invention, are not threatening to us because of their eagerness to fight or to govern. I believe that they are generally a good deal less belligerent than some of their predecessors in these last twenty-five years. It is the delicate and dangerous gear with which they are charged that raises the specters of the consequences of accident, irresponsibility, or madness, common phenomena of any war, to such heights. And it is the latitude in making decisions for which the military is asking that suggests future perils for us. The military does not object to the decisions once they come; what they complain about is that getting the decisions through the civilian bureaucracy renders the strategic and tactical advantages of modern war equipages useless.

What is the value of computerized, highly mobile war gear, they ask, when the opponent can come back in an hour with a decision that takes us three days to make and transmit? It should be apparent that a major crisis of decision will some day, somewhere, once and for all tumble the system whereby ultrasonic weapons and their attendants are controlled by the ponderous machinery of nineteenth century decision-making processes.

It is clear that weapons diplomacy, the application of force as the trump card in international relations, is archaic. Worse, it is useless. To think otherwise, one is forced to ignore the microsecond weapons systems which have created such an unbearable crisis in international political decision-making processes everywhere, especially in the democratic societies.

My contention is that it does not have to be left this way; that perhaps before it is institutionalized completely, the scientific community can make a massive attempt to balance the war system which they have bestowed on the republic with devices and systems to block its use. They can decide to turn a portion of their interest from the redundancies of thermonuclear overkill and the diversions of outer space to the aid of the political process and the real defense of the free society. Specifically, I am asking if it is not possible to build into the framework of democratic governing processes advanced technological systems that will give us a chance to understand the current conditions and attitudes of the rest of the world, its peoples, and its leaders; devices that will enable us to abort crisis situations or, once they are upon us, provide us with alternatives to violence.

There are obstacles to any significant movement of science toward a concentrated assault on problems of this magnitude. For one thing, they are hard. Science, for all its awesome façade, now likes to do easy things. A large portion of the physical science population has been immersed in polishing inventions twenty or more years old. The behavioral and social sciences, bemused by access to electronic counting gear, each year load the trade magazines with projects of increasing triviality. In spite of some progress, the scientific pecking order is still much as it has been, rigidly segregated by craft status and increasingly insulated, one discipline from another, by staggering inventions of professional syntax.

In a very few areas, attempts are being made to attack the problems of the social and political orders by at least asking questions of the technicians stultified by their long tenure in the weapons business:

What, if anything, can the wondrous machines do to help us assess the hopes, fears, and aspirations of the world in a continuous way? Is there, for example, nothing science can do to close the technical gap between doorbell-ringing opinion-gathering methods and the capacity of the million-bit memory drum, which is now sometimes diverted to such uses as predicting the best bus schedules from California to a Nevada gambling house?

Is there no better way to guide our governors than by the guesswork of the people who have elevated themselves to the role of "operations analysts" and who, for lack of our possession of better methods, profoundly affect the gravest decisions of history?

What, we ask, is "credibility"? Is it the same to one man as it is to another?

In the same patois, what is "rational behavior"? Is it the same to an Israelite as to a Formosan, to a Japanese as to a Nebraskan?

What are the components of "threat" that finally tote up to being "intolerable"?

Can incipient paranoid behavior out of the forces of complex circumstances be predicted in a people or their leaders? If not, a useful understanding of mass behavior is not foreseeable, and most of psychiatry, psychology, and a good deal of physiology must be marked off as limited individual therapeutic techniques.

The questions go on, inferentially urging all the disciplines of science to consolidate and press a fraction of the ingenuity and energy that has gone into the war system toward an information gathering and analysis system that can begin to help us out of the horror that by 1965 will cause the equivalent of thirty-five tons of TNT to be assigned to the personal containment of every human being then living on the globe.

Walter Lippmann has warned that neither the United

States nor Soviet Russia must push the other beyond that point of provocation and humiliation at which even the most rational nation "can be provoked and exasperated to the point of lunacy where its nervous system cannot endure inaction—where only violence can relieve its feelings. It is the business of government to find where that line is—and to stay well back of it." And, I would add, it is the business of science to help government find and hold the line.

Science must mount an unprecedented effort to furnish government with an assessment system that draws on the pertinent knowledge of all its branches and to transmit it in usable form to the managers of the political and the military systems. The scientist no longer has the right to remain apolitical. These efforts will have to be launched, maintained, argued, and defended by individual scientists. For example, since money is not only the lubricant but the propellant of scientific development, the scientist himself must start to influence the disposition of governmental research and development funds.

I am *not* asking for an overlying organization of scientists to tell us what to do and how to do it. I *am* asking for the attention of the individual scientist who is now immersed in weaponry or in the Next Fifty Years at Bell Labs. Science and its common-law wife, technology, have bathed long enough in the adulation of the popular press and in the awe in which great segments of the society have held them because of their creation of such impressive murder machines. Now they must turn to inventions of far greater novelty, complexity, and importance. The mounting of the thermonuclear war machine has stultified international order and crippled our hopes to revive it by traditional political and social means. Now science must somehow furnish us a parallel system of equal impressiveness under which their highly refined system of murder machines may be controlled.

Lynn White, Jr.

About a hundred and thirty years ago Auguste Comte schematized human history in terms of three ages: the age of religion, the age of philosophy, and the age of positive knowledge or science. He had faith in science, and his positivism is the heart of modern orthodoxy. All of us today take for granted that humanity is progressing from bondage to mastery of the natural environment, from superstition to knowledge, from darkness to light. It is axiomatic that science is the exploration of an endless frontier and that its processes cannot be reversed or even seriously interrupted. Every American or European, every Asian or African deeply influenced by Western culture, has implicit trust in the inevitability and rightness of this onward sweep of science. Even the churches embrace the new orthodoxy, if they are judged more by what they do not say than by what they say.

The modern positivist is a man of faith as much as was the medieval mystic. The concept of human destiny secularized by Comte was evolved by Joachim of Flora, a Cistercian abbot of the late twelfth century, who divided history according to the Trinitarian dogma, equating the ages of the Father, the Son, and the Holy Ghost with an age of fear, an age of love, and an age of freedom. Joachim's vision was taken up by the left wing of the Franciscan movement and broadcast over Europe. It was inherent in the thinking of late medieval and early modern proletarian revolutions and underlies the Marxist straight-line notion of human destiny. When Comte transmuted Joachim's formula, he was replacing one faith with another closely related to it.

No faith can afford to reign unexamined. Our habit of regarding scientific progress as inevitable may in fact be dangerous to its continuing vigor. In every civilized society something that can legitimately be called science has existed, but the amount of energy put into it has varied enormously. In every age minds of great ability are attracted to the focus of cultural interest, be it the fine arts, literature, religion, science, or something else. If the cultural climate shifts, the concentration of intellectual energies and capital investments follows.

Science must have a positive emotional context to thrive, as well as economic and political encouragement. Legislatures and corporate bodies must reach decisions favorable to science, and investors and voters must approve what their representatives do. Parents must want science in the education of their children. Above all, a significant proportion of the ablest minds must choose to dedicate themselves with passion to scientific investigation if the movement is to progress.

The modern outburst of scientific activity is not necessarily permanent. The cultural support that science enjoys today rests more on fear of foreign enemies and of disease than upon understanding, and fear may not be a healthy or lasting foundation. Science needs its statesmen, and statesmanship demands the long view. The future of science, like its past, will be largely a matter of accident unless measures to assure its continuance are attentively sought. Since the energy that civilization expends on any activity depends on the cultural climate, the important question today is: What can be done to insure an affirmative social context for science?

The historian has no ready answers. No professional historian thinks that history repeats itself. History does not foretell the future, but study of the past may provide some keys to understanding. Above all, knowledge of history should liberate us from the past and enable us to be vividly contemporary. Viewing human experience in vastly different circumstances helps to dislodge presuppositions, and may free our ideas about what needs to be done to assure the future of science.

The prestige of science today sustains a common but false assumption that any robust culture must have had considerable scientific activity. Now Rome was immensely vigorous. Languages descended from Latin are still spoken from Tijuana to Bucharest. The overwhelming mass of legal structures of the world, not only in Europe but in Asia and the Communist countries as well, is descended from Roman law. The Romans had vast creative ability and originality; yet there was no ancient Roman science. Nothing that can be called science existed in the Latin tongue until the twelfth century. From our modern point of view, Roman indifference to Greek science was absolutely spectacular. It has been argued that by the time of the Roman Empire Greek science was so far past its great days that it could not attract the vigorous Roman mind. But distinguished Greek scientists, such as Galen, lived for long periods in Rome. As for the "petering out" of Hellenic science, one of the most original Greek scientific thinkers, Philoponus of Alexandria, was contemporary with Justinian in the sixth century. Greek science was available to the Romans, but was ignored.

Even more disconcerting is the case of Islamic science. During some four centuries, from roughly 750 to 1150 A.D., Islam held the lead in scientific activity. In the eighth century a government-supported institute of translation emerged in Baghdad. Very nearly the complete corpus of Greek science and a major part of Indian science were made available in Arabic within about eighty years. Original scientific work began appearing in Arabic by the late ninth century, especially in mathematics, optics, astronomy, and medicine.

In the early tenth century Al-Razi, an Islamic physician, produced a book known eventually in Latin as *Liber Continens,* an encyclopedic codification of Greek and Hindu medicine, including a great deal of Al-Razi's own observation. It is probably the biggest single book ever written by a medical man, and is a superb work. In 1279 it was translated into Latin for Charles of Anjou by a Jewish physician of Agrigento in Sicily. It was published in Brescia in 1486 and reprinted four times before 1542. It was a fundamental medical reference book for centuries, and was entirely absorbed into the stream of Western medicine. But perhaps the most striking thing about it is that no complete copy of Al-Razi's great medical encyclopedia exists in Arabic. It was practically forgotten in Islam after a few generations.

The Arabic-speaking civilization knew what science was and was proficient in it. For four hundred years science was one of its major concerns. But a crystallization of other values occurred in the late eleventh century which shifted the whole focus of Islamic culture. Science was abandoned, and abandoned deliberately.

Christianity's relation to scientific activity has varied greatly through the ages. It has been said that early Christianity killed Greek science; but Christians were no more indifferent to science than were contemporary pagan Romans. The early Christian attitude was based on the view that natural phenomena were relatively unimportant. Only spiritual values had significance. The natural world deserved attention solely because God used it to communicate specific messages to the faithful.

This concept of the function and nature of the physical world is illustrated in a sixth century story about Pope Gregory the Great. Gregory, not yet Pope, had seen English slaves in the Roman slave markets, and decided to evangelize this pagan people. He received permission from the then Pope and started for England. On the evening of the second day out, while he was resting and reading, a locust – *locusta* in Latin – hopped up on his book. He knew that God was speaking to him. The Latin words *loco sta* mean "stop"; he took this to be the meanng of the message and went no farther. The next day couriers from Rome reached him and summoned him back. The people of Rome had demanded that the Pope recall Gregory from what would have been a lifelong mission because they desperately needed his leadership.

It is plain that science could not flourish in a culture that held to such a "rebus" interpretation of natural phenomena. But by the twelfth century this attitude began to change, at least in the Latin West. People began to pay more attention to the physical world. Sculpture of the early Gothic period clearly shows that the artist looked at real vegetation when he carved ornamental leaves or flowers. In the thirteenth century St. Francis of Assisi supplemented the doctrine that material things convey messages from God with the new idea that natural phenomena are important in themselves: all things are fellow creatures praising God in their own ways, as men do in theirs. This new notion opened a door to natural science, and partly explains the enthusiasm for experimental science in the Franciscan order at that time.

Another concept crucial for the whole development of modern science was emphasized in the thirteenth century and found its clearest spokesman in the Franciscan friar Roger Bacon. He said that there are two sources of knowledge of the mind of God—the Book of Scripture and the Book of Nature—and that each of these must be searched by the faithful with equal energy. He pointed out further that study of the Book of Nature had been sorely neglected.

This idea, natural theology, changed the role of men from passive recipients of spiritual messages through natural phenomena to active seekers for an understanding of the Divine nature as it is reflected in the pattern of creation. Natural theology was the motivational basis of late medieval and early modern science. Every major scientist from about 1250 to about 1650, four hundred years during which our present scientific movement was taking form, considered himself primarily a theologian: Leibnitz and Newton are notable examples. The importance to science of the religious devotion which these men gave their work cannot be exaggerated.

Why did the idea of an operational natural theology emerge in the thirteenth century, and in the Latin West alone? There was no similar development in Greek Christendom. It may have sprung from the key religious struggle of the time, the battle of Latin Christianity with the great Cathar heresy. Early in the thirteenth century looked as though the Cathars were going to get control of a strip of territory extending from the middle Balkans across northern Italy and southern France almost to the Atlantic coast, separating the Papacy from the more orthodox areas of northern Europe. The Cathars' major doctrine was that there are two gods—a god of good and a god of evil. The visible universe is the creation of the god of evil, which means that living a good life involves having as little as possible to do with physical actuality. Christianity holds that matter is the creation of the one good Diety. In the process of upholding the Christian position against Catharism, natural theology assumed a new relevance and vividness.

Natural theology was unquestionably a major underpinning of Western science. By the time the theological motivation began to diminish, Western science was formed. Today the motive force of natural theology has long been spent, and it does not seem to have been replaced with any other idea of equal power. Are modern scientists quite sure why they are pursuing science? Science is fun, and the exhilaration of the chase may keep it going for a long while. But will scientific advance continue without more serious impulsion?

Scientists must become increasingly aware of the complexity and intimacy of science's relationships to its total context. The modern tendency to regard science as somehow apart from, or even dominant over, the main human currents that surround it is dangerous to its continuance, and can be harmful even to progress within science. The veneration of the circle is an example of a general presupposition that constricted even so great a scientific mind as Galileo's. Galileo, in bondage to the axiom that the circle is the perfect curved form and therefore necessary to any significant speculation, could not seriously contemplate Kepler's thesis that the planets move in elliptical orbits. He neither accepted nor refuted Kepler's notion. He committed the unforgivable sin: he disregarded it.

Fixation on the circle was almost complete in ancient culture. The Romans recognized only three ovoid forms: in arenas, in shields, and in the bezels of rings. Pagan Scandinavians used the oval for a type of brooch, but discarded it as soon as they were Christianized, i.e., Mediterraneanized. The Middle Ages had no oval forms except occasionally the nimbus surrounding Christ in scenes of the Last Judgment or the Ascension, and even this was a version of the ancient Christian fish symbol, pointed at both ends. As late as the fifteenth century, artists could not draw a picture of the Coliseum which showed it oval. The first ascertainable oval design in a major European work of art is the paving that Michelangelo designed in 1535 for the remodeling of the Capitoline Piazza in Rome. Michelangelo and his successors during the next fifty years created an atmosphere in which ovoid forms became respectable, until finally Baroque art was dominated by the oval. Kepler's astronomical breakthrough was prepared by the artists who softened up the circle and made variations of the circular form not only artistically but also intellectually acceptable.

While the sanctity of the circle long impeded science by closing avenues of speculation, another inherited classical idea of a very different sort restrained progress by divorcing thought from practice. Manual labor was extolled for seven hundred years by monks, especially the Benedictines, as being not merely expedient but spiritually valuable as well. With the late medieval revival of Greek and Roman attitudes, however, the classical contempt for manual labor reasserted itself. The universities emerging in the thirteenth century had faculties in the liberal arts, law, theology, and medicine. Medicine was the only discipline with an embarrassing manual aspect, and in order to retain their prestige the medics separated surgery from medicine. Surgeons did not want to be downgraded either, so surgery became largely theory. There are pictures showing a professor of medicine lecturing to students, while a theoretical surgeon in turn directs a barber surgeon who dissects the cadaver. Medicine advanced during the latter Middle Ages, but it seems likely that it advanced less rapidly than would have been the case if the study of surgery, anatomy, and medicine had been carried on by the same people. Speculation too far removed from substance is often of limited value. The trend to purge university curricula of "vocational" courses may contain a seed of decay.

Current discussion of the problems of maintainin scientific progress usually focuses on the importance of providing an adequate economic base for science and creating an atmosphere of political and intellectual freedom in which science may flourish. But, as we have seen, changes in science in the past have also to be related to changes in basic religious attitudes, in aesthetic perceptions, and in social relationships. More of our attention should be directed to an examination of the sources of our faith in science today, and to the wellsprings of motivation that lead men to pursue science. Why does a man become a scientist? Why does he choose his manner of work, and how does he select the area that engrosses him? The answers to questions like these are not entirely economic or political.

Our science itself may contain unexamined axioms, like the circular prison that held Galileo captive. Hypnotism is an example of a phenomenon that science has not really tried to explicate, apparently because in some way it seems outside accepted categories of "reality," although it has been used in amazing ways in dentistry and surgery.

A distinguished surgeon told me about a delicate heart operation carried out under hypnotism, and added "That sure is fooling them." But who is being fooled

The continuation of civilization as we know it depends on science, and the continuance of science would seem to depend on our ability to examine this sphere of human activity objectively and relate it to its human context. Those responsible for the statesmanship of science must develop a scientific understanding of science itself. They must become increasingly aware of the intricacy of the ecology of the scientist. We must learn to think about science in new ways unless we intend to leave the future of science to chance.

September 1963

FEDERAL SUPPORT OF BASIC RESEARCH

by John Verhoogen
University of California, Berkeley

Summary

There is no simple formula to relate the level of Federal support of basic research to economic or military needs; because basic research is, by definition, concerned with the unknown, its returns per dollar spent cannot be predicted on grounds other than the observation that, so far, they have been, culturally, socially, and economically, very great indeed.

A guideline to a policy for science may perhaps be found in the proposition that our rate of progress in science will depend mostly on the quality and quantity of available brainpower. The first step must then be to insure that scientists and potential scientists are provided with adequate opportunities to develop, demonstrate, and exercise their creative powers. Ideally, every scientist who is capable of raising a valid scientific question, and of contribution significantly to its answer, should be given the means to do so. Research in universities supported in large part by Federal grants should remain the backbone of Federal policy. The largest share of funds for basic research should go to general-purpose agencies (e.g., the National Science Foundation) rather than to mission-oriented ones (e.g., National Aeronautics and Space Administration); the National Science Foundation, in particular, needs considerable budgetary strengthening. A general increase in research funds of 10 to 15 percent per year for the next 10 years may be appropriate.

Introduction

We ask an answer to the question: "What level of Federal support is needed to maintain for the United States a position of leadership through basic research in the advancement of science and technology and their economic, cultural, and military applications?"

A few preliminary remarks are in order:

The question, as formulated, assumes that the United States now has a position of leadership in the economic, cultural, and military applications of science. The assumption is important, because it might seem to follow that the level of support of basic research that has established such leadership should also be sufficient to maintain it, at least for the next few years. We note, however, that our military supremacy, or whatever part of it science is responsible for, is still, and we hope will remain, untested. The United States has without doubt mastered the technology of many fields; but brilliant engineering achievements are not to be seen exclusively in the United States, and our technological supremacy does not extend to all fields. Where we do lead, the margin is not invariably very wide, and it is conceivable that at the present rate of development other countries might surpass us in many respects in a decade or less. Nor is it clear that we lead in social or cultural aspects of science. Our rate of progress in the social aspects of medicine is notoriously slow; the philosophical and cultural implications of science seem to receive more attention abroad. The number of Nobel laureates compared to total population is not highest in the United States. Complacency and self-admiration are never helpful. What is needed is not just to maintain our position, but to improve it.

A second remark pertains to the word "basic," as applied to science. Basic research, as we understand it in this report, is that part of scientific inquiry that is in essence nonprogramatic. It is motivated primarily and simply by curiosity, by the desire to know and understand without regard to any practical applications that may arise from it. But the dividing line between basic and applied science is at best an elusive one, if it exists at all. Whatever the differences in motivation may be, their requirements and procedures are often identical, and although basic science is usually thought to precede applied science, the feedback from the latter to the former is by no means negligible. The two are inherently difficult to dissociate. For the purpose of the present report, it may be convenient to draw the dividing line where the ratio of cost to direct applicability becomes large; therefore we do not consider research of the type that can be supported by the industry that will derive immediate returns from it, but will include much of what some might consider to be "applied" research.

Two Features of Modern Science

There are two characteristics of modern science that must be kept in mind. The first is its all-pervasiveness. There is no need to repeat here what has been said many times about the scientific revolution we are now living. It is a fact that science now molds our daily lives to a degree unimaginable 50 years ago. And it is also a fact that if we were to shut down our laboratories and burn our scientific libraries, our society would not survive very long under its present form. The trend will continue; science, which has been felt so far mainly in technology and medicine, is now spreading to all human affairs. The second characteristic is that as science progresses the cost of each new bit of information increases as it becomes more difficult to obtain. Exploring the surface of the earth, for example, is relatively cheap compared to the exploration of its interior. These two trends explain why governments are increasingly called upon to support science: both its scope and cost now vastly exceed the resources of a private institution or group. The 18th century was the age of the single investigator working in his own private laboratory. The 19th century saw the development of universities well capable of serving with their own resources the scientific needs of the time. The 20th century must look at the matter in quite a different way.

Science and the Military

We now turn to our central theme, which is to assess the proper level of Federal spending in basic research, and consider first the effect of science on national security. World War II and the years thereafter offer a stunning picture of the speed with which scientific discoveries move from the realm of "pure" science to become instruments of survival. From this picture two lessons must be learned. The first is that this Nation must not find itself, as it did in 1941, in a position where, for lack of previous adequate support of basic science at home, its fate depended to a large extent on knowledge obtained abroad. The second lesson is that as no one knows what the next weapon will be, basic research must be carried out simultaneously on many fronts, including many seemingly implausible ones. Few people would have thought, 10 years ago, that national security could in any way depend on, or be related to, for instance, fundamental research in seismology.

Thus, although military considerations unequivocally demand basic research on a broad front, the long-range unpredictability of military needs precludes any precise evaluation of what would be an adequate level of expenditure. Clearly, we need science; but just how much is enough? Only history may tell.

Science and Economic Growth

Very much the same situation exists with respect to the level of support of basic research needed for economic growth. The relation between the two is still most tenuous and obscure. Although the most prosperous countries are also those where inquiry flourishes best, it has been pointed out that the two industrialized nations that devote the highest proportion of their gross national product to research and development—the United States and Great Britain—are not the nations that have had in late years the fastest rate of economic expansion; the extraordinary recovery of Germany after World War II was not based on science, at least not on German science. The discrepancy may be accounted for in a number of ways. It may perhaps suffice to point out in the first place that basic science does not necessarily and invariably precede technology; historically the Industrial Revolution preceded the scientific one, and James Watt invented the steam engine long before the laws of thermodynamics on which it operates had been formulated; our knowledge of aerodynamics was still very meager when the first airplanes appeared in the sky. Secondly, some industries apparently grow very well without having to spend much money on research. Finally, the "leadtime" between scientific discovery and its technological application is still large, on the order perhaps of 20 years or more in some instances. If it is true, as stated recently by Lord Todd, that the "seeds of any large technological developments to be made in the next 20 years are already with us," it follows that money spent today on basic research may not bear its economic fruits much before 1980. This timelag could in all probability be reduced if needed, for it seems to depend much on the effort put into development; yet on the whole it might increase rather than decrease, for as science becomes more sophisticated, more esoteric, more abstract, and as its ideas become increasingly remote from "common sense," it will presumably take them longer to reach the design engineer. The industrial utilization of gravitational energy that keeps "quasars" going will certainly require much more time than that of nuclear power.

What all this adds up to is, again, that although science does in a general way lead to economic growth, the proper level of support of basic research cannot be determined by a simple formula from economic considerations only; there is as yet no practical way of estimating possible economic returns of money spent on general basic research.

Science and Culture

Even in our pragmatic culture, usefulness is not the sole criterion of merit. Basic research has a much broader justification in that the quest for knowledge is one of man's most characteristic and vital urges; the desire to know is perhaps what most sharply separates him from beast. Most of human history can be read as an incessant query, the search for answers to unceasing questions: What is the stuff of the universe, and why; what is life, and how did it start? It is properly mankind's heritage that knowledge is an essential aspiration—to give insight into the circumstances of our existence, and to give us freedom from fear of natural forces.

To put it simply: Human beings want bread, and they want freedom, and some of them want to know.

At this point it is not inappropriate to consider the close relationship of science to a free society. Is it accidental that the 18th century produced at the same time the first great burst of basic science and the first great step toward free democratic societies? Is it mere coincidence that the American Constitution and the French Declaration of Human Rights are contemporaneous with the great mathematicians, physicists, chemists, geologists, on whose work all of our modern science still rests? Many have considered the relationship between a free society and the scientific spirit to be fundamental. A democratic society, it is said, is one that is uniquely favorable to the scientific spirit; conversely, a society is more likely to prosper and remain free if it fosters in all its citizens the spirit of free inquiry, the desire to know, the search for new and better ideas, and the curiosity that are basic ingredients of science. Even though science has occasionally been misused, and scientists have supported undemocratic philosophies, it remains true that allowing the scientific mind free play is a means of strengthening the individual freedom of mind without which a democracy may find it hard to survive.

It should be pointed out, in fairness to other aspects of culture, that science is not unique in promoting democratic welfare: Philosophy and the arts are just as indispensable as science. The study of history is surely a better guide to political wisdom than is quantum mechanics. It has been said again and again that science cannot flourish when divorced from the humanities, and to that view we subscribe. Support of science must entail support of the liberal arts. A full discussion of this matter should properly find its place in a report on governmental support of education, which is not the subject of this paper; let it suffice at the moment to remind the reader that good science requires good education, in the broadest acceptation of that term.

Federal Role in Science

Convinced as we are that the pursuit of science is an essential function of our present society, we have nevertheless reached the conclusion that the proper level of spending on basic research cannot be determined from economic or military considerations only. The point is that basic research being, by definition, concerned with exploration of the unknown, we simply cannot predict what the returns per dollar spent will be.

We have, of course, no historical precedents to guide us. We do not know of any society that collapsed from overspending on basic research, nor is it clear which societies, if any, have collapsed from underspending. The idea of governmental support of research is, forgetting the alchemists, not much more than 30 years old. Prior to that, peace-time research was conducted almost exclusively in universities, in industrial laboratories, themselves not much more than 60 years old, and in a few governmental specialized agencies (e.g., U.S. Geological Survey). Governmental support of research on a broad scale began to appear in Europe in the 1920's; large peacetime expenditures on research in this country really date from World War II. The form of governmental support has changed rapidly in the past, and presumably will continue to do so in the future. How can we then, in such changing and largely unpredictable conditions define the Federal responsibility?

A Tentative Guide Line

A tentative guide to a policy for science may perhaps be found in the observation that the most important ingredient of scientific progress is, of course, the scientist himself; the size and quality of our scientific enterprise will be determined by the quality and quantity of the available brainpower. Science consists of much hard work and a few brilliant ideas; we need many well-trained, intellectually alert, and thoroughly competent scientists to assemble the facts, and we also need the extraordinarily gifted—and therefore very rare—individuals who, starting from the facts, create significant ideas. The ratio of the two varies much from field to field; in mathematics, for instance, only the very few most creative brains really matter, whereas in other fields we still need very much to assemble the verifiable facts on which new ideas may grow. It follows that our rate of progress in science will depend mostly on the quantity and quality of available brainpower. As the judgment of quality can be made only by judging achievements, the first requirement in a policy for science should be to provide opportunities for scientists and potential scientists to develop, demonstrate, and exercise their creative powers.

Research in Universities

Opportunities to develop and exercise creative power exist, of course, in universities; it is, in fact, the prime responsibility of the universities to provide them. Such opportunities consist, first, of exposure to excellent teaching. But teaching, however good it may be, is not enough. One does not become a good scientist just by listening to lectures, or even by performing a routine piece of experimental research. What counts most is the intellectual atmosphere, the stimulation and excitement of seeing research done and results achieved, the development of inquisitiveness, the spirit of adventure, the willingness to follow one's own mind wherever it may lead. All this thrives best where research itself is thriving; good research in the universities is a prerequisite to good research anywhere.

The matter of Federal support of basic research in institutions of higher learning has been considered in detail in a recent Academy report. We need only repeat briefly some of its conclusions: Research project grants should remain the backbone of Federal policy; what is most needed is a liberal system of individual grants ("little science") of the type now administered, for instance, by the National Science Foundation; we also need (1) institutional and general research grants; (2) small and largely "uncommitted" grants to young scientists on the basis of a very general outline of their interests and the endorsement of their seniors; (3) a selective program of research grants to weaker institutions that could be raised to a higher level of excellence. Suggestion No. 2 seems particularly pertinent, for it is probably from the group of young scientists who have not yet made a name for themselves that the most vigorous and original ideas will come.

"Little Science"

The essence of this proposal is that, ideally, every scientist who is capable of raising a valid scientific question and of contributing significantly to its solution, and who is not already supported by industry or by private or state funds, should be given an opportunity to do so by means of a research grant. A competent scientist probably profitably spends about $20,000 per year on the average. The number of competent scientists with good ideas is hard to estimate; it is certainly less than 100,000 and possibly in the neighborhood of 50,000. The total expenditure nationally would amount to perhaps $1 billion per year.

The main problem that obviously faces us here is the judgment of quality: What is a good proposal? That judgment could perhaps best be made by panels of experts, as is currently done, for instance, in the evaluation of National Science Foundation proposals. In fact, the method of evaluation could lead to a practical method of determining the proper annual appropriation for "little science;" it should be commensurate with the total sum requested during the previous year for proposals rated "good" by scientific advisory panels, the rating being made independently of available funding.

"Big Science"

"Little science" grants, by definition, would go mostly to single scientists or small groups of scientists, working in small laboratories with equipment that can be made or bought for, say, less than $100,000. There are, of course, scientists whose work centers around large "machines" and to whom "little science" grants are not very useful, as the main cost of their research lies in the capital investment of big tools: Telescopes, oceanographic vessels, high-energy accelerators, for example. Clearly also, a greater number of scientists will find themselves in need of large computers which, like telescopes, cannot be bought on ordinary research grants. The "little science" program must therefore be supplemented by a "big science" program of capital investment. A number of planning reports outlining the needs of the various branches of science are now being prepared, so that it is premature to guess what the total will be—perhaps of the order of $500 or $1,000 a year.

General Support of Graduate Schools

Grants to university investigators are unlikely to be productive if the investigator himself has no laboratory to work in; he also needs a library, shops, and free time. All this is presently beyond the means of many smaller universities, so that the Federal Government must be prepared to provide increasing support to graduate schools, and may well have to provide most of it to institutions of emerging excellence. National Science Foundation appropriations in this field are still very modest and should increase rapidly. In addition, and because the advancement of science is inseparable from progress in the arts and humanities, as noted above, a form of support broader than can presently be provided by the National Science Foundation may have to be devised to secure well-rounded growth of the undergraduate colleges that feed the new graduate schools.

Science in Federal Agencies

Not all basic research is done in universities or private institutions: Federal agencies such as the Weather Bureau, the Bureau of Standards, the Geological Survey—to mention just a few—are concerned with research as basic as that pursued anywhere. It is of the highest importance that such programs be strengthened, and that the agencies be maintained at a high level of efficiency and productivity. In the first place, their research, e.g., meteorology and weather prediction, is commonly of a kind and scope that cannot be carried out in universities. Second, competition in science is good, and Government agencies may set standards of excellence in research that private institutions should equal or surpass. Finally, it is difficult in a free society such as ours to insure that science will move forward with the necessary vigor on all fronts; at times there are likely to be "fashionable" research topics that attract general attention while other equally important fields lie neglected and fallow. By a judicious choice of its own research program, the Federal Government can to some extent correct the imbalance.

Allocation of Funds

The difficult point arises here as to how funds should be allocated among the various branches of science. Of a total of approximately $1.4 billion obligated for basic research in fiscal year 1963, about 32 percent went to the National Aeronautics and Space Administration and only 11 percent to the National Science Foundation. Admittedly, research is more expensive in some fields than in others; nevertheless, a ratio of 3 to 1 of space-oriented research as compared to all other fields supported by the National Science Foundation must raise some questions, for we submit that no single branch of science can in the long run be more important than any other, or than all others. Because it is inherently impossible to predict where the most significant discoveries will be made, adequate support should be available at all times in all fields, and the allocations of research funds should be determined primarily by the scientific merits of the proposed investigations. Research in mission-oriented agencies comes under a different category, for the decision to carry out such missions (e.g., man on the moon) is not primarily motivated by its scientific importance; whether such expenditures are justified or not is not entirely a matter for scientific judgment. The large items for mission-oriented research in the Federal science budget tend to obscure the fact that funds for general-purpose research are still very low. The need to strengthen general-purpose agencies, and particularly the National Science Foundation, cannot be overemphasized.

The Need for Continuity

A further argument for gradually shifting the support of basic research from mission-oriented to general-purpose agencies is that the support of science must be continuous. Unlike public works, science cannot be turned on and off again. Industrial plants can be set up and properly staffed in a relatively short time; laboratories and universities cannot. It takes years to train a scientist, and it may require many more years for his work to mature and bear fruit; likewise, any disruption of scientific activities can have lasting effects. Science in Germany, for instance, still shows today the adverse effects of political events of the 1930's. A policy for science must of necessity be a long-range policy, as money spent today may not show its beneficial effects for many years to come. Responsibility for carrying out a policy for science should rest primarily in permanent agencies set up for that purpose.

Conclusions

The general theme of this paper may be summarized as follows: Science and technology have become so closely woven into the fabric of our society that we simply cannot do without them. Yet the relation of basic research to economic growth remains elusive; because basic research is, by definition, concerned with the exploration of the unknown, there is no way of calculating in any serious way the probable economic returns to the Nation of investments in science, and there is no formula for relating the level of support of basic research to short-range military or economic needs. But even though it may be difficult, if not impossible, to disentangle the respective contributions of science and technology to economic developments and material progress, it seems evident that enormous returns have indeed accrued from the very small sums spent on basic research up to and including the first half of this century. There is no reason to suspect that things might be different in the future.

For want of a better criterion, I suggest that our scientific policy be based on the premise that the best chances for scientific progress lie in giving competent scientists who have valid scientific questions to ask an opportunity to work out the answers. Research-project grants should remain the backbone of Federal policy, as discussed in a recent National Academy of Sciences report (*Federal Support of Basic Research in Institutions of Higher Learning,* National Academy of Sciences, 1964).

In practical terms, this recommendation means that the level of spending on basic research should be such as to allow funding of all meritorious research proposals, the judgment of merit being made on purely scientific grounds by appropriate panels drawn from the scientific community.

The total rate of spending implied by this policy is very hard to estimate: Perhaps about $4 to $5 billion per year 10 years hence. This figure is, admittedly, a very rough guess. It was arrived at by the simple expedient of multiplying the Federal obligations for basic research in 1963 by a factor of 3. The factor 3 was chosen because the level of spending on science depends roughly on the number of scientists, and that number is not likely to more than double in the next 10 years; an additional factor of 1.5 was included to allow for increasing costs (per scientist) of work performed in some fields. Large as this figure may be, it should be remembered that an increase by a factor of 3 in 10 years means a rate increase of only 11 percent per year. Expenditure of $4 billion for science as a whole 10 years hence does not seem excessive if the exploration of space alone is now worth $5 billion per year.

What the Federal budget for science should ultimately be is, of course, not a proper matter for scientists to decide; all I wish to do is point out what I think scientists could usefully spend in the near future. But whatever the figure will be, it is important that the largest share of the money for basic research should go to general-purpose agencies rather than to mission-oriented ones—e.g., the National Science Foundation rather than the National Aeronautics and Space Administration. The reasons for this are, first, that as no one knows in what field the most significant discoveries will be made, research must be pursued on a broad front; and second, support of science must have more continuity than can be provided by agencies that could conceivably be terminated when their mission, or part of it, has been accomplished.

Scientists and American Science Policy

Who speaks for science? The future offers more dilemmas than unequivocal answers in science policy.

Wallace S. Sayre

The phrase "scientists and American science policy" suggests other comparable formulations: soldiers and American military policy, diplomats and American foreign policy, farmers and American farm policy, businessmen and American business policy, educators and American education policy, labor and American labor policy, and a host of other variations. These parallels serve to remind us sharply of the limitations which a democratic order places upon the role of experts as well as upon special interests in the shaping of public policy. If it can be said, for example, that war is too important to be entrusted to the generals and peace too important to be left to the diplomats, then it may be asked whether science policy is not too important to be delegated wholly to the scientists. In a democratic order all policies of significance must secure a wide range of consent, not merely from the general public but also among the many organized groups and institutions that see their interests importantly involved. Scientists do have a special involvement in science policy, but under the rules of a democratic society they have no monopoly in its development or maintenance, nor have they inherently any greater legitimacy or relevance as participants than all the other claimants who aspire to influence the content of science policy.

Scientists, we may assume, aspire to be influential as a group in the determination of public policy over a wide range, especially those elements of public policy which may be described as "science policy." To exercise such influence the scientists must enter the political arena. Scientists in politics encounter the questions posed by the political process to all those who enter: who are they? who speaks for them? what are their goals? what are their strategies?

Who Are the Scientists?

If scientists are to be influential participants in constructing an American science policy, they will need to be self-conscious participants—that is, they must have a visible and concrete identity. That identity is now vague and elusive—to many scientists as well as to the other groups involved in the policy process. "The scientific community," a phrase often submitted as an identification, is a world of uncertain boundaries.

Who are the members of the scientific community? Is it an open community, hospitable to all who desire to enter, or is it open only to those who meet severe tests of eligibility? More specifically, are there "hard scientists," whose membership is taken for granted, and "soft scientists," whose credentials are dubious? Are physicists and chemists members of the scientific community by right, while other natural scientists must submit additional claims for admission? Do all engineers qualify, or only certain types of engineers? Do doctors of medicine have entry, or only research scientists in medicine? Are social scientists full members of the scientific community? The answer of the moment appears to be that the natural scientists are the most fully accredited members of the science community but that the life scientists and the social scientists regard this as a transient condition of affairs.

The difficulties raised by these questions suggest that "the scientific community" is most often used as a strategic phrase, intended by the user to imply a large number of experts where only a few may in fact exist, or to imply unity of view where disagreement may in fact prevail. The phrase may thus belong in that class of invocations, so familiar to the political process, which summon up numbers and legitimacy for a point of view by asserting that "the American people," or "the public," or "all informed observers," or "the experts" demand this or reject that. There is nothing especially astonishing about this, since all participants in the political process indulge in the stratagem, and each participant learns to discount the claims of others, but there may be ground for mild surprise that the code of science permits its extensive use by scientists either as deliberate strategy or in genuine innocence.

If scientists are themselves uncertain as to who all their fellow scientists are, then some ambiguities attend their relationship to American science policy. Are they a small elite group (for example, the approximately 96,000 named in *American Men of Science* for the physical and biological sciences), or do they number several million (as they do if the engineers, the social scientists, and the medical profession are included)? If scientists want to be among the shapers of American science policy rather than simply the objects of that policy, then they must expect these and similar questions from the other participants in the making of science policy. The spokesmen of science will be asked: For whom do you speak? The scientists themselves confront a prior question: Who are to be the accredited spokesmen for the scientists?

Who Speaks for the Scientists?

The notion of an American science policy, a policy with which the scientists are to be influentially identified, requires the scientists to have leaders who can act as their representatives in that bargaining with public officials and other groups which accompanies the policy-making process. Not every scientist can participate directly in this

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The author is professor of public administration at Columbia University, New York, N.Y. This is the text of a lecture presented 27 December 1960 at the New York meeting of the AAAS.

process; there is not room enough, nor time enough, for a town meeting of all the scientists with all the other groups that have equally legitimate claims to be present. Some few scientists must be selected to speak for the many, but the scientists may choose these few in many different ways. They may let the science spokesmen nominate themselves; they may let nonscientists select the leaders of science; they may develop nominating and electoral devices for choosing their leaders through the votes of all scientists in a single scientist constituency; they may choose their leaders in numerous specialized constituencies; or they may combine these methods in various ways, or invent still other methods.

Tradition and recent practice have already provided some important patterns of choice. The history of American science is rich with examples of the articulate, self-directing, individual scientist of high prestige who felt it his obligation to speak often and boldly in behalf of science and the scientists. Few scientists, and fewer nonscientists, have been inclined to question his representative role, although his peers in prestige and self-confidence have often publicly challenged his advice. Another pattern has been provided by the habit which high-ranking government science officials have of speaking, from their position of special eminence and authority, for the interests of science as they perceive them; this would seem to be, for example, the primary function of some government science advisers and advisory committees. If these advisers are the spokesmen of the scientists, it is relevant to ask: What role did which scientists have in choosing them? Still another pattern has been demonstrated by the role of the National Academy of Sciences since 1863. This quasi-governmental body of scientists, its membership small and its new members elected on the basis of scientific eminence by those who are already members, has for many decades acted upon the assumption that it could and should speak for the scientists in the realm of public policy. The scientists who are not members of the academy have not invariably agreed that the academy spoke for them, or that its silence was to be taken as neutrality on their part on contemporary issues of science policy.

These patterns of individuals and small, elite groups, some self-nominated and some the designees of government officials, speaking for the scientists have been accompanied by several efforts to establish more comprehensive scientist constituencies from which spokesmen might be chosen. The American Association for the Advancement of Science is the most durable of these constituencies. Its own membership is large, and its affiliated societies enlarge its base. Its officials, and especially its committees and its journal *Science*, often speak eloquently for the values and the priorities of science and the scientists. One of the most dramatic assertions of its representative role as spokesman for the scientists was its 1958 Parliament of Science, assembled in Washington, to consider the proposal for a government department of science and other issues. Some privacy surrounded the identity of the delegates to this "parliament," the method of their selection as representatives of the scientists, the record of their deliberations, and the extent of their agreement upon the terms of the published report of the "parliament." The sense in which the AAAS and its "parliament" are authentic spokesmen for the scientists as a scientific community thus cannot be easily determined, either by scientists or nonscientists. The Federation of American Scientists provides still another variation—an association of scientists quite explicitly committed to participation in the political process.

But the most prevalent pattern for choosing the spokesmen of the scientists is provided by the specialized associations of scientists. The officers and committees and journals of the American Physical Society, the American Chemical Society, the American Institute of Biological Sciences, the Federation of American Scientists, the Engineers' Council, the Association of American Geologists—and perhaps a thousand other specialized societies—provide the scientists with hundreds of spokesmen in their specialized areas of interest. These spokesmen do not often speak with one voice upon a given aspect of science policy, nor do they often if ever concern themselves with the elements of a comprehensive science policy. Instead, the leaders of each specialized society tend to express their views upon that segment of science policy which touches significantly the interests of the society's own members. As spokesmen for the scientists, their voices are often competitive, emphasizing separate priorities, asserting specialized rather than general goals. In this characteristic the associations of the scientists share the pluralistic, fragmented, and internally competitive attributes of the other group participants in the American political process —whether political parties, business, labor, agriculture, the professions, nationality groups, or the governmental bureaucracies.

The leaders of still other groups often speak confidently in policy discussions as surrogates for scientists. The Association of Land Grant Colleges and Universities, the American Association of University Presidents, science laboratories and institutes, and the science communication media are prominent among these groups. Do they, too, hold a watching brief for scientists by the scientists' own choice?

Who, then, speaks for the scientists? The answer would seem to lie somewhere in a broad zone of ambiguity. Only the scientists themselves can identify their authentic spokesmen. If they have already done so, it would seem to have been done privately and to have been kept confidential. When and if the scientists undertake an explicit identification of their spokesmen, it is not improbable that they will conclude that no one can speak for all of them, and that in a democratic society we will all, perforce, continue to be confronted by numerous, competing spokesmen for science, each often claiming to speak for more of the scientific community than he in fact represents.

An American Science Policy

Uncertainty thus surrounds the questions: Who are the scientists and who speaks for them? Ambiguity also characterizes the phrase "American science policy." It is not difficult to cite examples of particular science policies; these exist in abundance—from the patents clause of the Constitution to yesterday's progress reports of the National Science Foundation. But the unity and comprehensiveness implied by the phrase "American science policy" are not achieved by merely consolidating and codifying all these separate items of science policy. Something more than this is quite clearly implied and evidently desired by many of those who speak for the scientists. It may be assumed, then, that an American science policy is something aspired to but not yet achieved by the scientists: a unified, comprehensive, coherent, rational statement of goals and methods for science in the United States, accepted by and binding upon all the participants in the policy process, and including agreement upon the rules by which the policy may be changed.

The main elements of such a policy might include the following.

1) A preamble, asserting the values of science to society and the nation; a statement defining the boundary line between the governmental and the private sectors in science.

2) A statement of the priorities for science in each of these sectors.

3) A ranking of the competing claims of science education, basic research, and applied research, as well as an assignment of priorities among the fields of science—chemistry, engineering, physics, biology, psychology, economics, and perhaps a score of others.

4) A statement of agreement and action upon the structure, location, and assignments of the science agencies in the Executive branch—for example, a unified science department (or, alternatively, decentralized science agencies) and the relation of such a department or such agencies to the President and the Congress.

5) Explicit statements of governmental procedures intended to reflect the values of scientists in such matters as secrecy, personnel loyalty and security, government contracts and grants for research, definitions of "basic" research, and provisions concerning the "chain-of-command" in science activities, including protection for the autonomy of individual scientists.

If such a body of public policy existed, accepted by the scientists and legitimatized by the President and the Congress in a statute, thus attesting the consent of the nation, then an American science policy in the fullest implications of that phrase would have been established.

Is such a unified and comprehensive policy a feasible goal for American scientists? Do they in fact desire it?

If a 1961 Town Meeting of Science were to be assembled, despite the problems of deciding which scientists were eligible to attend, agreement could no doubt be reached on the preamble to an American science policy. Preambles, like political party platforms, are usually triumphs in ambiguity. A viable consensus could probably also be reached on item 5—the "working conditions" for scientists—although ambiguity would overshadow precision here, too. But beyond these two items the available evidence suggests that there are no other major elements of an American science policy upon which one could expect unanimity, or even a clear majority agreement, among the scientists themselves. The document which might emerge from the work of such an assembly of science would most likely be an unstable mixture of vague agreement and sharp minority dissents, a testament to the pluralism of science and the scientists. And if the scientists are not likely to agree upon a unified science policy, the prospects that the nonscientist participants might develop such a policy are even less convincing. There are no apparent powerful incentives for any other great interest group in the American society to develop a unified, comprehensive science policy. And even if agreement were possible among the scientists, there is no persuasive evidence that they could win consent without major concessions to the competing claims of all the other interests that must, in a democratic order, agree to such a significant allocation of social values and resources.

Unity and comprehensiveness are thus not likely to be the hallmarks of American science policy. Talk of a single, comprehensive "American science policy" has an essentially fictitious quality. There will be many science policies, rather than a master science policy. Diversity, inconsistency, compromise, experimentation, pulling and hauling, competition, and continuous revision in science policies are more predictable continuing characteristics than their antonyms. This has been the history of American science policies and this describes their present state. We are accustomed to view this state of affairs as deplorable. But to live with diversity and accommodations of policy, and yet to be impatient of them, may be the process by which a democratic society achieves progress in science as well as in other fields. In any event, the future seems to offer American scientists more dilemmas than unequivocal answers in science policy.

Persisting Dilemmas for Scientists

Some of these dilemmas may be illustrated by a brief exploration of a few of the choices concerning governmental arrangements for science—choices which some scientists have helped to make in the past, or which nonscientists have made for them, and still other choices which must yet be made.

Science advisers. One of these choices involves the aspirations of scientists to give advice to officials at the highest levels of the national government—advice not simply in an area defined as "science policy" but also concerning those elements of foreign policy, defense policy, and domestic policy to which many scientists believe their specialized knowledge is relevant. These aspirations of scientists were reflected in the establishment of the National Academy of Sciences a hundred years ago and in the creation of the National Research Council almost fifty years ago. They are reflected today in the existence of the office of Special Assistant to the President for Science and Technology, the President's Science Advisory Committee, the office of Science Adviser to the Secretary of State, and the General Advisory Committee of the Atomic Energy Commission. The Council of Economic Advisers is still another example.

Attempts to define the role of these advisory institutions raise several important questions. Is their primary responsibility to advise the officials as an autonomous voice of the scientists, or are they, as agents or colleagues of the officials, to explain official policies to the scientists, or are they to participate in working out those accommodations in policy which will build a bridge of collaboration between scientists and officialdom? The history of these institutions of advice reveals the tensions, as well as the temporary adjustments, between these inherently competitive conceptions of the advisory role. For the scientists the dilemma remains unresolved: an autonomous science adviser is soon at the periphery rather than at the center of policy making; an involved adviser is soon the advocate of all official policy rather than its critic, an ambassador from the officials to the scientists rather than the scientists' spokesman, or at best a broker between the scientists and the officials. The scientists who are dismayed by these hard choices may perhaps find some consolation in knowing that all other groups in a democratic order confront similar frustrations.

A department of science. Another choice involves the recommendation for a unified department of science, or for a department of science and technology. This proposal to concentrate most of the talents and other resources of the scientists in a single agency, and "to give Science a voice at the Cabinet table," is a strategy supported by the precedents of comparable aspirations in agriculture, business, and labor. But the proposal encounters today, as it has since John Wesley Powell advocated it before the Allison Commission in the 1880's, the stubborn pluralism of the scientists themselves, the uncertainties of the scientists about the boundaries of their interests, and the opposition of government scientists more willing to endure their existing, familiar organizational environment than to risk the unknowns of a new and untested arrangement. With the scientists thus embattled among themselves, neither the nonscientist interest groups nor the public officials now seem likely to take a determined initiative on a question the scientists, as such, cannot decide. A department of science, then, waits upon the unlikely event that the scientists will soon be able, and will find it desirable, to decide who they are, who their accredited spokesmen are, and what their common goals are, and, most important, able to conclude that they are sufficiently unified to risk their separate interests to the leadership and fortunes of a single government institution.

An autonomous science agency. An alternative choice—the creation of an autonomous science agency, but with a limited assignment—has been at least temporarily decided upon. The National Science Foundation has completed its first decade; its durability now appears convincingly demonstrated. The independence of the agency from the supervision of officialdom is not as great as was hoped for by those spokesmen for the scientists who piloted the proposal through the hearings, the amendments, the debates, and the votes of the 79th and 80th Congresses, past the shock of a Presidential veto indicting excessive autonomy, to the eventual compromise enacted by the 81st Congress. Some of the form, and more than a little of the substance, of autonomy was lost along the way. Annual budgets and annual appropriations are continuing reminders that autonomy is limited, even in decisions about kinds and amount of basic research, and even after sputniks gave the agency higher priorities and the scientists greater authority.

A close look at the composition of the National Science Board since 1950 also raises the question of whether the agency does not more nearly reflect the autonomous voice of university and other administrators of science, alumni from the ranks of scientists though they be, than it does the voice of scientists in the classrooms and laboratories. The task of representing the scientists on the Board has apparently, with the passage of time and with the entry of Presidential and other preferences, been entrusted more to surrogates for scientists than was the expressed expectation of the sponsors and the officials in the discussions accompanying the passage of the National Science Foundation Act of 1950. Surrogates perhaps provide "virtual" or "existential" representation for the scientists; other groups in American society must often accept a similar settlement.

Specialized science agencies. Most existing government science organizations represent a different kind of choice for scientists. These science agencies are immersed in the political system of a large department or "independent" agency, the degree of autonomy of the science unit in that system varying widely. The life scientists, for example, occupy many special units in Agriculture, in Health, Education, and Welfare, and in Interior; the nuclear scientists are found in the Atomic Energy Commission, and other physicists and chemists, in the Bureau of Standards; meteorologists staff the Weather Bureau; scientists of many varieties inhabit Defense Department units; while the geologists have their sanctuary in the Geological Survey, the space scientists have theirs in the National Aeronautics and Space Administration, and the economists have theirs in the Council of Economic Advisers. The other social sciences are less visibly accommodated, but they do staff numerous units in Agriculture, in Commerce, in Health, Education, and Welfare, and in Labor.

The leaders of all these science units have links, strong or attenuated as the case may be, to the associations and institutions of scientists outside the government, but inside the departmental or agency system they share the powers of decision and compete for priorities with other members of the executive hierarchy, and they report to congressional committees whose concerns are not confined to questions of science or the preferences of scientists. In these many science enterprises the scientists are partners with nonscientists rather than autonomous decision makers. They may employ the *mystique* and the *expertise* of science as strategies to maximize their autonomous role, but they cannot realistically expect to be more than senior partners. Most frequently they will be compelled to accept the status of equal partner with nonscientist officials; not infrequently they will find they are actually junior partners. Their hopes for autonomy are, in practice, curbed not only by nonscientist officials in the executive hierarchy and by congressional committees but also by the activities of the interest-group associations in the science bureau's own special constituency. Thus, the Bureau of Mines must listen attentively to the American Mining Congress and the United Mine Workers; the Bureau of Standards, to many industry associations; the Weather Bureau, to the Air Transport Association and the Farm Bureau Federation; the Public Health Service, to the American Medical Association and the American Cancer Society; NASA, to the aviation industry associations; the Atomic Energy Commission, to the electric power associations and many contractor groups; and agricultural research bureaus, to the Cotton Council and numerous other commodity associations. Rare is the science bureau which is not required by its political environment to bargain continuously with, and accommodate its aims and its priorities to, the interest groups in its constituency.

Advice to Congress. Science agencies in the Executive branch have occupied most of the attention of scientists. If they are to pursue their aspirations for a more distinctive and influential role in science policy, the scientists will find it necessary to formulate a general strategy concerning advice to Congress from scientists. No congressional committee is now organized and staffed to give exclusive and comprehensive attention to science policy and to listen continuously to scientists, although the House Committee on Science and Astronautics takes a broad view of its science role, and its Senate counterpart may follow suit. Most scientists must pursue their congressional interests across almost the whole range of committees and subcommittees in both Senate and House. If unity and comprehensiveness in congressional action on science are desired—unity such as is sometimes proposed for science in the Executive branch—scientists will be required to choose among several apparent alternatives: they can propose a joint committee on science and technology, with a wide-ranging jurisdiction over all the concerns of scientists; or they can propose a comprehensive committee on science and technology in each House, rather than a joint committee; or they can aim at the creation of a joint committee on science policy with a more limited assignment, or of such a committee on science policy in each House. If changes like these were to be made in congressional science committees (an event to be anticipated only after long and determined effort), the scientists still could not expect to enjoy a monopoly of attention from the new committees. Those other groups who now share power with the scientists' spokesmen in the numerous specialized committees and subcommittees would follow the scientists into the new arenas of influence. The scientists might, however, hope to have, at least for a time, higher status and legitimacy as spokesmen before such new committees, and they might also hope that their competitors in the new setting might compete with each other as well as with the scientists. The question which would soon confront the scientists, however, would be, could they establish and maintain their own unity of goals and priorities before the new committees? The odds in favor of an affirmative answer do not seem to be high.

Politics Inescapable

Scientists influential in the creation, maintenance, and modification of American science policy are scientists in politics. The spokesmen for the scientists need not be party officials nor candidates for, or occupants of, elective public office, but they will have to be active participants in other phases of the political process—as high government science officials, as science advisers to executive officials, as spokesmen for science policies before committees of Congress, as organizers of opinion through the communication media, as officials and leaders of science associations and institutions. The leaders of the scientists cannot escape politics and remain leaders in science; since their leaders cannot escape politics, the scientists as a whole are in politics too—even their silence is interpreted as acquiescence.

Leading American scientists have long entered the political arena with boldness and success. Convincing examples are provided by the zeal and skill with which the Scientific Lazzaroni piloted the National Academy of Sciences through the Congress and secured Lincoln's signature in 1863; by the subtlety and determination with which Powell secured the establishment of the Geological Survey in 1879 through an appropriation bill rider (a technique that is of the essence of politics); by the frequency with which the Cosmos Club has served as the meeting place of an informal caucus of scientists planning the strategy for a scientists' *coup d'état* in the public interest; by the magisterial role of Vannevar Bush in national science policy; by the sophistication of the Federation of the Atomic Scientists in their 1946 attack upon the May-Johnson bill and their shaping of the terms of the McMahon Act.

Scientists in politics share the problems of other participants in the political process. No special dispensation exempts the scientists from the hard choices and continuing difficulties which the political process imposes upon all those who aspire to shape public policy. One course is to seek to maximize the unity of all scientists and to establish legitimacy for the spokesmen of a unified science community. An alternative is to accept diversity and competitive priorities among scientists and to establish the identity of the separate groups of scientists, establishing the legitimacy of their respective spokesmen. Whichever of these two main roads is chosen, the united or the separated scientists will face the necessity of recruiting allies from among organized groups of nonscientists; the scientists cannot exercise a unilateral dominance in the making of science policy. Alliances are created and maintained at a price; the price takes the form of mutually acceptable accommodations in policy or priorities. Scientists in politics meet with varying fortunes in the process of bargaining with allies and opponents: in the Bureau of Agricultural Economics they find an environment too severe for survival; in the National Institutes of Health, an embarrassment of riches; in the Weather Bureau, high-velocity cross-winds of pressure; in the Geological Survey, an atmosphere of quiet and modest benevolence which has existed for a half century, since the belligerent initial decades; in the Bureau of Standards, a favorable equilibrium of forces, but in the Public Health Service, an unsteady equilibrium. Such variations are the common experiences of most participants in the political process. The conditions which determine the range of variation are best understood, anticipated, and managed by those who are politicians—that is, by those who are expert in the political process.

The 1958 Parliament of Science states the scientists' hopes and fears in persuasive terms.

> This scientific revolution will totally dwarf the Industrial Revolution and the other historical instances of great social change. It will be more compelling, and will pose more urgent problems, because of both the pace and the magnitude of the changes which now impend.
>
> What faces man is not, in any restricted sense, a scientific problem. The problem is one of the relation of science to public policy. Scientific issues are vitally and almost universally involved. The special knowledge of the scientist is necessary, to be sure; but that knowledge would be powerless or dangerous if it did not include all areas of science and if it were not effectively pooled with the contributions of humanists, statesmen, and philosophers and brought to the service of all segments of society.
>
> What is to be done? Scientists certainly have no arrogant illusion that they have the answers. But they do want to help. They are, moreover, convinced that the time is overripe for a more understanding collaboration between their special profession and the rest of society.

The scientists are now inescapably committed to politics if they hope to exercise influence in the shaping of public policy, including science policies. The leaders of the scientists, then, are perforce politicians. As politicians in a democratic order, they are effective in the degree to which they understand the political process, accept its rules, and play their part in the process with more candor than piety, accepting gladly the fact that they are in the battle rather than above it. The spokesmen for science have occasionally lectured the nonscientists, sometimes sternly, upon their obligation to understand science. Perhaps the advice may be reversed: the scientist has an obligation to understand, and to play his significant role forthrightly in, the polity (*1*).

Note

1. In the preparation of this article I have drawn upon the bibliography given below and upon data developed through an extensive series of interviews with science officials in Washington during 1959 and 1960 and from a study of pertinent official and unofficial documents—a project supported in part by the Council for Atomic Age Studies, Columbia University.

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SCIENTISTS ON TAP OR ON TOP? WE ARE MISSING THE REAL ISSUES

The smoke screen of traditionalism which now seems to be directed toward discussion of the place of the scientist in public affairs obscures the substance of the problem. The real issues to be considered go beyond the place of the scientist in public affairs. It is much more important to determine in what way science and technology, both now and in the future, can contribute to our goals and objectives as a nation and to the welfare of mankind as a whole.

The scientist . . . has not only fostered change, but has also lived with change. He knows full well that theories and concepts represent only working hypotheses. He is acclimated to change in his thinking processes—for he knows that intellectual utility is the criterion for the success or failure of his attempts to organize, classify, and extend knowledge. There is no ultimate conceptual "truth"—for what is considered true today is that which follows a conventional pattern of thinking. The path of progress in science is littered with the refuse of discarded concepts which could not surmount the obstacles of new knowledge.

The scientist is dedicated to change—even though he too, like any other human being, often allows emotion to sway his otherwise nonemotional and impersonal approach to the solution of purely physical problems. He will attempt to overextend his theories and concepts beyond their usefulness—because he, too, like many others, identifies his accomplishments with himself. Often he does not realize that his scientific contributions are products of the age in which he lives. Perhaps this is why the statement is so often made that the great scientific advances are usually made by scientists of the younger generation—they are not bogged down in the mire of traditionalism. . . .

Scientists have become the nouveau riche of modern intellectual society. The traditional "four hundred" whose business it has been to analyze trends in government and politics constitute those who are presumed to have inherited the right to do so by training. By and large they serve a useful purpose, but they do resent the intrusion of the come lately scientist. They have flooded scholarly journals and written books galore on the place of the scientist in public affairs; they have debated the question of whether the scientist has any right to go beyond his scientific expertise to make political decisions and have invoked the two cultures polemic in defending their traditional positions. . . . But the real issue is beclouded because of their inability or unwillingness to comprehend the changes which are taking place through scientific discovery and technological innovation. The real issues do not involve personalities and academic prerogatives. The real problems are substantive political, sociological, and economic problems. How can we adapt ourselves to change and how can we use science and technology in the battle for survival? How can we improve our relations with our fellow men through the proper assessment of the scientific and technological factors which have and continue to change the world today? After all, politics is essentially practical human relationships. Our political scientists would do well to pay more attention to these new parameters that affect so markedly our relations with our fellow men, rather than insist that the past alone is the guide to the future.

Perhaps I have given the impression that the scientist is in a better position to develop policy than those who now have such responsibilities. Actually, I feel that we as scientists need to become more aware of the political, economic, and sociological implications of our brain children. . . . We need to get our feet wet in the floodwaters of change which our scientific and technical accomplishments have loosed upon mankind. This goes beyond the common enterprise of the world scientific community which has successfully built bridges of understanding between peoples of different cultures and political ideologies. Even here, the motivation is not necessarily impersonal because each of us as a scientist is seeking his place in history. At home and abroad, we attend meetings, publish papers, and lecture. We do this because we, too, like to have others think well of our efforts. We are also well aware of the fact that others in our own specialized fields of research think as we do—in fact, may be more advanced in their research ideas than we may be. We can learn from others and profit mutually from such exchanges of information. . . .

However, we also represent our country. The prestige achieved by individual scientists contributes to the national picture. Our position as the leader in science and technology contributes to national prestige—and prestige is a political factum. Scientific and technological preeminence helps to develop the proper "image" of American life among the advanced nations in the world. Our status in science and technology constitutes evidence among the rapidly emerging peoples of the world for the vitality of our system of government. Scientific and technological leadership, encouraged and so largely made possible by government support, has more meaning than merely the expansion of knowledge or the search for truth. It is encouraged as a matter of practical politics to make sure that we retain and maintain our leadership position in the world of today and in the years to come.

We could debate such questions as the place of scientists in policymaking. Has the scientist a right to participate in the decisionmaking processes which go beyond the management of scientific and technical projects? Is or is not the scientific method applicable to disciplinary fields which are less quantitative in character, possibly because they deal with "systems of organized complexity (Morrison)"? Surely such discussions are useful intellectual exercises. On the other hand, we live in a world which is markedly influenced by science and technology, in a world where the status quo is accepted by no individual or nation, and where our very survival and growth in a military and economic sense depend upon our ability to keep ahead of nations equally well-endowed in scientific manpower and facilities. What is more, the emerging nations have come to the realization that they too can achieve security, status, and economic well-being through science and technology. In other words, our existence as a political entity in a highly competitive world demands that we encourage and politically utilize our scientific and technological capabilities to the fullest extent.

Rather than resort to polemics which divide, let us take a good look at the gray area that lies between the social and the physical sciences. Evidences of the sort of cooperation which is needed are already apparent. Many of the more advanced universities are developing programs to explore this interdisciplinary area which Wright has called science affairs. Scientists themselves are being called upon by government at the highest levels to engage in decisionmaking and in formulating policy. Their opinions are being voiced in print, congressional hearings, and widely-quoted addresses. The desire to explore the interaction between science and technology and foreign affairs has become important in projects supported by various foundations. The State Department has recognized that science and technology impinge on the formulation of foreign policies and has established an office of International Scientific and Technological Affairs, appointed scientific attachés at many of our embassies, and has conducted a successful seminar on science, technology, and foreign affairs at the Foreign Service Institute [see May *Bulletin*, p. 43].

Let us coordinate our efforts in seeking the solutions to problems which plague the world today, recognizing full well that unacceptable political ideologies take root in the swamps of human misery and despair. The social scientist needs to become more aware of the scientific and technological parameters which have overturned and obsolesced traditional disciplinary thinking and methodology; the physical scientist must descend from his ivory tower, and realize that his achievements affect the life and living of people and nations, both on a national and international scale. The scientist must develop a greater awareness of the sociological and economic changes wrought by what he has done —and participate actively in the solution of the resulting political problems.

L. F. Audrieth

Urbana, Illinois

THE SCIENTIST AS PUBLIC ADMINISTRATOR

Lewis C. Mainzer
University of Massachusetts

SACRIFICE of a research career for one in research administration is common among scientists in the United States today.[1] It is paradoxical that so many men desert a highly respected, even idealized, way of life, for which their professional training and experience have prepared them, to enter an occupation whose very professionalism is suspect. The research administrator stands in an area of ambiguity and transition in the meaning of work: though he enjoys considerable prestige in society and salary and power advantages over researchers within bureaucratic organizations, the actual conduct of research has been at the core of the image of the good scientist.[2] If "a man's work is as good a clue as any to the course of his life, and to his social being and identity," [3] basic elements in the scientific career and the bureaucratic system may be illumined by understanding the changing of roles by the scientist. Is the scientist who becomes an administrator misled by ambition and then corrupted by power, or is he enabled to realize a fuller potentiality and make a unique contribution? To answer this, two subsidiary questions must first be examined: Why do men leave research to become administrators? Does the researcher-turned-public administrator remain always the scientist, or are his attitudes toward politics, science, and administration those of the administrator?

Where other sources are not indicated, the analysis presented below relies heavily upon a series of interviews with Washington area federal research administrators. Two dozen or so each in the National Institutes of Health, the Agricultural Research Service, and the Navy, plus some research scientists in these agencies and some Budget Bureau and Civil Service Commission officials, were interviewed. The administrators, most of whom had been trained as scientists, were representative of a variety of ranks and functions, though purposely bunched toward the top. Interviewees, none of whom objected to the taking of full notes with the guarantee of anonymity, spoke in response to a statement of the purpose of the research and specific questions appropriate to the person, agency, and level. The writer did not feel that it was impossible to discriminate qualities of openness and perspicacity in those interviewed. Conversational interviewing was no doubt facilitated by the cathartic value to many persons in talking about themselves to a detached observer, the ability of men within a formal organization to learn a good deal about close colleagues, the

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Note: The Brookings Institution, through an appointment as Visiting Professor, and the University of Massachusetts Research Council, through a grant, facilitated this study. Each is innocent of the consequences of its generosity.

[1] Of over 200,000 scientists registered in 1960 with the National Register of Scientific and Technical Personnel, about one-fourth listed their work activity as "management or administration." *Scientific Manpower Bulletin,* No. 17, April 1962 (Washington, D.C.: National Science Foundation, NSF 62-11).

[2] Harvey L. Smith writes that every profession operates in terms of "a basic set of fictions about itself," which "tend to concentrate the rewards of prestige in some areas of professional activity and to ignore others." "Contingencies of Professional Differentiation," *American Journal of Sociology,* 63 (January 1958), 413.

[3] Everett Cherrington Hughes, *Men and Their Work* (Glencoe: Free Press, 1958), p. 7.

appeal of an objective research project to persons brought up in a society in which belief in science is pervasive, the interviewer's identification with a university and a Washington research institution, and the blessings bestowed upon the work by top administrators in each agency. The writer was deeply moved by the willingness of these men, manifested by a significant proportion of those interviewed, to examine themselves with probing honesty.

Why Scientists Become Administrators

Career and the Range of Satisfactions

Men often find reward in more diverse occupational activities than they would admit or suppose. For example, professionally active men may enjoy the armed services during wartime, perhaps because of release from responsibilities, competition, or meaninglessness, or because of comradeship, command, or subordination. Like the civilian professional-turned-soldier, a scientist who becomes an administrator was a complete man, not simply a "scientist," which is an abstraction, focusing on certain training, attitudes, and activities of the individual. Even one who has found satisfaction in research may sacrifice it without pain and find pleasure in other work.

Entry into a profession generally requires a great investment of effort and a major commitment by the neophyte, but is based on something of a guess. A youngster in the United States, if he is not a victim of poverty or physical or psychological deformity or cultural prejudice, may have a wide choice of occupations. Typically he makes his decision on the basis of vague knowledge of his own talents and of the requirements, actual work, and rewards of the various occupations.[4] He chooses early, with little experience and little real advice, even from well-meaning but generally permissive and uninformed parents. For instance, one who enjoys mechanical activities and does well in school courses presumed to be related to engineering may fix on engineering as a career. An early decision in this direction may mean, one study suggests, that a young man goes through engineering school before recognizing that he "would prefer to work more directly with people than with materials." [5] The same process may occur with the boy who enjoys science and does well in science courses, but who later feels that it touches only some of his interests and capacities, and would welcome the chance to develop his "human" interests as well. Administration is an outlet for these nonresearch interests.

Many scientists-become-administrators eased into administration gradually. Superordination begins naturally in the scientist's relationship to the student or laboratory assistant. Scientists regularly direct personally the activities of one or more others, and are used to not doing with their own hands everything professional that they seek to accomplish. Also, because modern science involves the bureaucratic organization of many men, large sums, and expensive equipment, it requires a great deal of formal administration at varied levels. Committees on grants and fellowships abound, giving scientists a taste of organized decision-making: the medical scientist assumes administrative responsibilities in the hospital; the university scientist is assigned to faculty committees; other environments offer special administrative occasions.

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[4] Cf. Morris Rosenberg, *Occupations and Values* (Glencoe: Free Press, 1957). Richard L. Meier, "The Origins of the Scientific Species," *Bulletin of the Atomic Scientists,* 7 (May 1951), 169, 173, confirms the lack of information in the choice of profession by scientists, but discerns a change in this situation.

[5] Eli Ginzberg, *et al., Occupational Choice; An Approach to a General Theory* (New York: Columbia University Press, 1951), p. 191.

While directing a few others in research, the scientist may still be giving most of his time to his own research. The chief who directs a small group, though bearing administrative responsibilities, is still concerned with the substance of research; the higher level chief is involved primarily or solely in administration. Frequently despite intentions to the contrary, his own program of research is dropped completely. He is concerned with promotions, hiring, space, equipment, assistants — the whole realm of "support" of research. These support decisions have great practical consequences for the subordinates and real psychological significance for them. Not to be supported adequately, where resources are apparently available, is an invitation to trim sails or leave. To make such decisions is to administer, to wield power.

In sum: (1) scientists often find satisfaction in the administrative function — perhaps to their own surprise, after the dreams of youth, the indoctrination of graduate school, and the challenges of the laboratory; (2) scientists easily become increasingly involved in administrative activities in the course of a normal research scientist career in the United States today. The administrative option is generally close at hand, and no abnormality of motives or circumstances is required to reach out for it.

Motives for Change

Chance plays a part, and no doubt some scientists who would have done well at administration are never offered the opportunity, while other researchers enter administration really by accident. However, something more than chance is at work. Discussions by scientist-administrators of their own motives and careers and of those of other scientists-turned-administrators whom they have known well suggest the following classification of motives and circumstances underlying the move from research to administration.

Men of quite varied ability enter administration because they seek advancement. Sometimes a strongly driven scientist seeks the salary, prestige, and power that go with hierarchical rank. Such a man may or may not deeply enjoy science, but he wants the obvious marks of success, whatever he does. On a more modest level is the man of decent but limited talents, who wants promotion and finds it available only by entering administration. Probably he dangles in mid-bureaucracy, making minor contributions, as he would have done had he remained a researcher. At all levels of competence, then, are men who give up research to gain the rewards, modest or substantial, which administration offers them. We can, however, specify circumstances and motives beyond simply the desire for advancement.

First, there are men who have not achieved real scientific distinction, never are likely to, and know it well. They may be perfectly adequate researchers, but they come to see that they can never make a really major contribution: "I will never win a Nobel prize." They do not hate administrative routine, nor do they shy away from authority. Administration seems to offer release from the strains of not succeeding in science on the grand scale of graduate school dreams, and it brings money, prestige, and other rewards, so they take the opportunity when it comes. Though they probably enjoyed many aspects of the scientist's life, they are not undergoing a traumatic experience when they leave research; often they see this in themselves. Colleagues, too, recognize this, and may resent it if these former researchers become aggressive administrators, confidently stating what research should be undertaken, how it should be organized, and who should be rewarded.

Second, there are men who were good, even very good researchers, but who, through advancing years (which may mean no more than forty years of age), begin to lose their imagination, vigor, confidence.[6] Younger men coming into his field with new and more sophisticated techniques (for example, mathematical learning of a sort he lacks) may make a man feel outmoded or outclassed. Similarly, if his specialty loses prestige and glamour while new branches attract energy and attention, he may feel he is an unexciting, old-fashioned fellow. Scientific research emphasizes drive, technique, imagination, ability to uncover new truth. In these qualities, young men often match or excel their elders. The advancing man — who is still only middle aged — may turn for haven to administration, which is assumed to require maturity, experience, and judgment, rather than continuing research prowess. People may say that "we have lost a fine scientist," but perhaps he has already done the best work of which he is capable. With his knowledge of science, his respect for good research, and his own high standing, he may usefully head a research program. His appointment may be good for himself, for the morale of his subordinates, and for the agency and program.

Third, there are men who are so good at administration that strong pressures are recurrently brought on them to assume administrative responsibilities. Such a man cannot easily remain within an organization and resist these pressures; perhaps against his will, he is forced from the laboratory more and more into administrative duties. He probably is a good verbalizer and a wide reader, thus impressing his more limited colleagues. He probably has great energy and self-confidence, a touch of charisma. He may be an outstanding researcher as well, or at least competent enough to be well respected. He may genuinely miss the laboratory and occasionally give up responsibility to return to research, but usually not for long. Actually he probably enjoys both administration and research and will never fully resolve his dilemma. Granted great prestige for both his research contributions and his high administrative post, he may nevertheless feel dissatisfied, because he is not keeping up with his area of science adequately and because his own research work has to be sacrificed. Being "strong" men, these administrators are likely to arouse intense loyalties or antipathies; they offer respectability, direction, and drive to an organization.

Fourth, there are men who believe strongly in a program, method (for example, interdisciplinary research), specialty, or particular theory. For such men, administration affords the means toward specific scientific or social goals. "Helping others to do their research" is a common rationalization among research administrators of their decision to enter administration, but before one can take this seriously as a motive, one must see it particularized. It is real, probably, when it is "helping others" to do something specific that the administrator thinks they ought to do, perhaps despite their own wishes, because it is important.[7] These administrators may use their organizational ability to accomplish large tasks, driven by faith in the outcome.

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[6] Some scientists continue productive research late, some may start late, some have a second flowering, but scientist-administrators testify strongly that tapering off is not simply a myth, however complicated the basic physiological, psychological, and social causes may be. Anne Roe, *The Making of a Scientist* (New York: Dodd Mead, 1953), pp. 45f., suggests the possible importance of early maturation and rapid decline of specific abilities as a factor in movement from research to administration. Cf. C. P. Snow, *A Postscript to Science and Government* (Cambridge: Harvard University Press, 1962), p. 16.

Scientists who come from outside government directly into public research administration may sacrifice not only research but the academic life. What has been said above is relevant, but we may also indicate as possible factors: interest in being at the center of a program, with the opportunity to act authoritatively (as in passing on grants) within one's scientific specialty; higher than academic salary; the special environment of Washington; and a change from normal routines of life. It is sometimes an honor to be asked to come to Washington to assume responsibility for a program in one's scientific area, and often these men must have had some taste of administration to whet the appetite.

These categories require a sympathetic reader, who knows that career is "a sort of running adjustment between a man and the various facts of life and of his professional world," "his laying of his bets on his one and only life," "a set of projections of himself into the future." [8] We recognize overlapping and irregularity, and will put no man on the rack to make him fit the categories.[9] It is best to emphasize the real variety of men and motives. Administrative power is for some a quiet haven and merely a job, for some an end in itself and a joy, for some a means to the top, and for some a sober duty — a self-sacrifice — to science, to colleagues, to noble purpose.

The Administrators' Thinking

What attitudes toward politics, science, and administration characterize the scientist-turned-public administrator? Were public research administration a well-established profession (or a group within a profession of research administration or public administration), shared attitudes might stem from professional school training, where traditions are inculcated, and perhaps from a professional association. Public research administration has not yet developed, as have the traditional professions, to the point where it provides a practitioner with "a subculture and an identity."[10] Each agency influences research administrators toward distinctive attitudes. Agency "personality" affects recruitment, morale, attitudes toward work, standing in the scientific community, and so forth. The attitudes of the administrator may reflect such characteristics of his agency as: (1) responsibility for an intramural or an extramural (grants or contracts) research program or both; (2) a programming approach to an extramural program or a more passive approach, responding to unsolicited grant applications; (3) treatment of the research program as an end in itself or as a means to a non-research goal; (4) emphasis on scientific competence or on administrative or political skills in advancing people; (5) emphasis on direction of or autonomy for researchers; and (6) intensity, the pace at which men drive themselves and others. The agency atmosphere, as well as the individual's experience and personality, contributes to shaping his job and his attitudes.

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[7] One able administrator entered government service at real sacrifice, including his own research, when offered a fine new facility and a large sum to recruit professional personnel; he was told he might do what he wanted with this new program. To turn down the opportunity, he explained, would be "like refusing a chance to go with Christopher Columbus because business is pretty good now."

[8] Hughes, *op. cit.*, p. 129.

[9] Dwaine Marvick, *Career Perspectives in a Bureaucratic Setting,* Michigan Governmental Studies, No. 27 (Ann Arbor: University of Michigan Press, 1954), categorizes high-level bureaucrats in an unidentified agency (which sounds rather like ONR) into institutionalists, specialists, and hybrids, distinguishing those who are "place-bound" from those who are "skill-bound" from those who are "free agents." Cf. William Kornhauser, *Scientists in Industry; Conflict and Accommodation* (Berkeley and Los Angeles: University of California Press, 1962), pp. 118–30. Focusing on autonomy versus integration of professional activity within organization, this study is useful respecting the strains between professional and bureaucratic goals. Cf. Simon Marcson, *The Scientist in American Industry; Some Organizational Determinants in Manpower Utilization* (New York: Harper, 1960), pp. 65–70, respecting the reasons why industrial researchers move into administration.

In light of the tenuous professional status of research administration, the distinctiveness of agency character, and the limited interaction and mutual influence of public research administrators, similarity of views may be traceable to independent attainment of truth or to the influence of similar experiences individually encountered.[11] The most obvious similar experiences are: contemporary American culture, probably middle class; college education, including graduate school; science training and research experience; federal government service; and research administration duties. These similarities of background and function in reasonable men often lead to similar views. Though the range of attitudes is wide, we can suggest the dominant view, the clustering toward one or another pole on a spectrum.

The Creed of the Research Administrator

On the basis of published and private statements we can draw up a "creed of the scientist" and a "creed of the public administrator," in terms of which to align the research administrators.[12] Each "creed" represents a distillation of widespread attitudes, not the views of any particular individual. To meet their polarizing function in this analysis, the assumptions of each creed are stated more explicitly and coherently and with less qualification and ambiguity than most scientists or administrators would state them. If the "creed of the scientist" inaccurately states current attitudes, it loses value in describing attitude changes in those who leave research for administrative duties, but retains analytic value as a pole in static description of the attitudes of these administrators.

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[10] Hughes, *op. cit.*, p. 129. One can distinguish the institutional arrangements (training schools, examinations, licenses, professional organizations, codes of ethics) from the psychological aspects (a feeling of lifetime commitment to the work as an art embodying a respected tradition of service) of a profession. Serious students of professions are hesitant to insist upon any precise definition of a profession, through various typical qualities or evolutions can be discovered. Cf. A. M. Carr-Saunders and P. A. Wilson, *The Professions* (Oxford: Clarendon Press, 1933), pp. 284ff.

[11] Despite real reservations one must have about his and other sociologies of knowledge, there are valuable insights into the relation between experience and ideas in Karl Mannheim's *Ideology and Utopia; An Introduction to the Sociology of Knowledge*, trans. Louis Wirth and Edward Shils (New York: Harcourt, Brace, n.d.), chap. I especially.

[12] Cf. Walter R. Schilling, "Scientists, Foreign Policy, and Politics," *American Political Science Review*, 61 (June 1962), 291–96, respecting the "policy perspectives . . . which seem moderately characteristic of many scientists, most of them physicists, who have participated in national security policy in recent times." Meier, *op. cit.*, compares chemists (politically moderate), engineers (conservative or apolitical), physicists (politically radical), and biologists (somewhat more varied). Respecting sixty-four top American scientists active in research, with comparisons among biological, physical, and social scientists, cf. Roe, *op. cit.* The journals *Science* and *Bulletin of the Atomic Scientists* are useful sources of the views of "spokesmen" for science. C. P. Snow's novels, *The Search* (London: Macmillan, 1958) and *The New Men* (London: Macmillan, 1954), are interesting on many of the questions discussed in this paper. Respecting American public administrators, Paul Appleby's works are especially useful. Kornhauser, *op. cit.*, pp. 58f., 138f., found that research managers in industry, especially at higher levels, tend to be oriented to bureaucratic, not professional, norms.

The "creed of the scientist" includes these assumptions: (1) scientific knowledge is the most certain knowledge; (2) science is the most profound kind of knowledge, revealing the beauty and meaning of the universe; (3) science is the most useful kind of knowledge, leading to invention and technological advance; (4) common-sense knowledge is unreliable; (5) scientists are objective, seeking only truth; (6) scientists are essentially men of peace, and science is a truly international language; (7) the most intelligent men today are scientists, and through the scientific method they can contribute to the solution of world problems; (8) we are in the "age of science," and science is basic to a good education; (9) more money and manpower and public appreciation should go to science; (10) politicians and administrators, lacking scientific training and unused to rational methods, are unreliable; and (11) the less political or administrative interference there is, the better the research program.

The "creed" of the public administrator includes the following: (1) common sense knowledge and "feel" keep agencies and programs going; (2) experience and sensitivity are the key qualities required for successful human dealings; (3) absolute truth would often be a foolish policy in human dealings; (4) the world is inevitably highly imperfect, as is human nature, but a good program is a useful social contribution; (5) it is difficult to change people's beliefs or patterns of behavior, and a proposal for major change requires strong justification; (6) any action which will anger a politician or group is suspect; (7) politicians, though they are sometimes apparently irresponsible, are not bad people, and one can generally reason with them; (8) experts and specialists vastly overrate their own importance, and are difficult to work with; (9) one can adjust to and live with most of the burdens an agency suffers, though outsiders do not realize the difficulties encountered; and (10) superiors often fail to give the program adequate support; subordinates, on the contrary, often fail to take an over-all view of the agency's needs, being enthusiasts for their own program. The creed of the scientist may be classified as essentially politically utopian, that of the administrator as politically realistic.

The federal research administrators interviewed seemed, above all, realistic in their attitudes toward politics, science, and administration. Most had no expectation of radical improvement in human nature or human relations through the techniques of science. There was little talk of science as a means to solving world problems or of scientists as new public leaders toward a better life. There was, of course, interest in and respect for science and confidence that scientists can often solve the sorts of problems for which their training equips them. There was natural agency enthusiasm and pride, but of the sort that any administrator is likely to express in talking about his program to a stranger.

Politics

Research administrators interviewed had a realistic view of politics, one close to the creed of the administrator. Especially as one rises in the hierarchy, administrators are not generally marked by despair over political interference. There is a phrase popular among Washington officials: "We can live with it." This is the typical attitude toward politics. Politicians are seen as men who are, on the whole, decent, intelligent, and cooperative, but whose political commitments and goals affect their behavior. The influence of politicians does not depress, disgust, or excite the research administrators.

Attitudes toward politics vary to some extent with the political experience of the particular agency. The National Institutes of Health have done remarkably well with Congress. Heading their appropriations subcommittees in House and Senate have been sympathetic, able supporters. Congress has consistently increased a budget which the executive has held stable. NIH administrators can scarcely help but think that Congress is kind to science. Department of Agriculture research programs have benefited less and suffered more from congressional intervention, so there is a less universal and unqualified confidence in Congress. There are differences, then, between those who have been very lucky and those who have had mixed luck.

Top administrators are not likely to be completely uninvolved in politics nor to have a complete distaste for it.[13] Many are quite skillful at it and genuinely enjoy it. Others emphasize their research interests and the scientific aspects of the job, as a protection against too great political involvement; but only in part can an administrator shape his role in this matter. Whether they glory in it or simply make the best of it, top administrators are close enough to politics to understand something of it. At lower levels, the administrator may have little or nothing to do with what he can identify as politics; it is a world that he knows by hearsay, and often one he would just as soon avoid. Some research administrators at lower hierarchical levels, not long removed from research positions, expressed an uncritical confidence in science and a complete distaste for politics and for mere common sense. One can hazard the guess that their attitudes will change as they gain administrative experience and climb the hierarchy, though a few men at high levels joined utopian rhetoric with administrative talent.

Scientific Freedom

Freedom usually bulks larger in language than in fact, because it runs counter to other values when decisions must actually be made.[14] Some scientist-administrators at high levels manifest a reverence for research and for the individual. Ill disposed to interfere, they have a deep sense of using and nurturing the talent and interests natural to a man, rather than regarding him as clay to be shaped. Where, for example, it is easy to punish a man who has gone stale, they seek to refresh him; he is too valuable to be regarded as finished. Many administrators see their job as one of protecting research subordinates against "improper" — the understanding of which varies among agencies — political or administrative demands from outside or above.[15] They serve as a buffer, warding off extraordinary political pressures and ignoring or modifying administrative regulations that would impede good work.

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[13] It is not unknown for federal research administrators deliberately to assume a scientific posture in congressional appearances, de-emphasizing administrative and political responsibilities and sophistication.

[14] This produces oddities, such as a naval laboratory where many members talk of the university atmosphere they enjoy; yet security regulations are very tight, there is much applied research, and the Navy is clearly present. Reference to a university no doubt helps morale, and for at least some men there is very wide scientific freedom.

The research administrators' attitudes toward scientific freedom were generally matter-of-fact. In units with a specific task, it is presumed that scientist members should contribute toward that purpose. The right to do "whatever you want" is defended only if the agency is not one that has to produce short-run practical results. In almost all instances, what the researcher undertakes must fit within the general scope of the agency program, though that may be very broad. In research units such as those within some of the operations agencies of the Navy, the justification of research by its practical results is, understandably, deeply embedded. In these cases, research blends into development and engineering and production, and it always faces toward the needs of the Navy. Individual curiosity is less likely to be revered in such a setting than in an agency with longer-range responsibilities and more academic connections, such as the Office of Naval Research, which contracts extensively with university professors. Even in the practically oriented Navy units, however, some research is sponsored which has a quite delayed military utility; administrators see the need for scientific discretion in such cases, but the basic assumption is that science can serve military needs.[16] Similarly, the organization of Department of Agriculture research largely by crop and animal specialties suggests that administrators generally expect practical findings within specified areas of work, though there have been serious attempts to foster basic research. Within units involved in more applied research, administrators usually feel less vividly the researcher's right to control his own work, and may recognize political or administrative influence on the researcher as more legitimate.

Research administrators' attitudes toward scientific freedom varied significantly but were, in sum, practical, decent, seldom romantic, sometimes hard. Certainly they assume the legitimacy of organization authority and the value of the goals pursued by the organization. They assume that some planning is possible in science and that their agencies do have specified areas of responsibility. They believe that not every scientist is highly original or likely to make a fine contribution if left alone; that the best men may easily be left to do largely what they want; that others will not suffer from some direction; that some must be led. The attitude is, in general, fairly realistic.[17] As one descends to the level of the administrator who is still a practicing researcher, general principles and policies respecting scientific freedom seem to be less important than the personality of the administrator, his attitudes toward and working methods with his subordinates. A first-rate scientist, who insists on freedom, may be a tyrant to his subordinates.

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[15] Concern by research administrators over public pressure for quick results in medical research is apparent in Senate Committee on Appropriations, 86/2, Hearings, *Departments of Labor and Health, Education, and Welfare Appropriations for 1961* (Washington, D.C.: G.P.O., 1960), I, 751, 843ff. Congressional pressure on research administrators, in terms of geographic areas and commodities to be emphasized, is amply evident throughout Department of Agriculture appropriations hearings.

[16] This is analogous to the approach in industry, where one also finds a wide range of attitudes toward discretion for researchers, but faith that research does pay, either in the short or long run.

[17] If one denies the authority of the organization and the value of its goals, one could defend much broader freedom. For analysis of the proper limits to scientific freedom and of present federal practice, cf. my "Scientific Freedom in Government-Sponsored Research," *Journal of Politics,* 23 (May 1961), 212–30.

Research Administration

Attitudes toward research administration vary markedly with rank. Those first entering administration still identify themselves strongly as scientists, more specifically as organic chemist or the like. This identification with an area of science clings tenaciously. It holds together the two halves of a man's professional life. Many a research administrator will, after hesitating over the question, decide he is a "biology administrator," or something of the sort, when asked his occupation. Quite near the top, membership in professional associations and some attempt to keep up in the field are often still found. There is a clear lessening of the real involvement with a scientific specialty and a clear increase of interest in and feeling for administration as one ascends the hierarchy. It seems certain that as the younger men rise their attitudes change.

Tested by regular interaction with significant mutual influence, or by their own conceptions, the federal research administrators are not a group.[18] There are some real groupings within the whole, especially among those, of whatever agency, concerned with a particular scientific area or problem. There is a sense of shared occupation, common problems, and need for cooperation among some of those in charge of grants programs. There are a number of formal organs that bring administrators together, but generally these relations do not go very deep.

The most important relations of these administrators are usually not with research administrators in other federal agencies. In the National Institutes of Health, for instance, relations with the medical schools are of primary importance, far more important than relations with most federal research administrators. In the Agricultural Research Service, relations with the state colleges of agriculture are of great significance, but most agricultural research administrators have few contacts with military research administrators. Each agency has its clientele and colleagues outside government. The National Science Foundation, the most obvious central unit, is not a major influence in government research agencies. Neither in their own conception of themselves nor in terms of talking to and influencing each other in daily operations are the federal research administrators really a group.

As their movement into administration is made easier, so their identification of themselves as administrators is made more difficult, by the weakness of professional bonds among American public administrators.[19] Federal research administrators generally hesitate to call themselves "administrator," do not become involved in public administration as a discipline or a conscious profession, and do not have great confidence in formal management training or theory. Administration often seems a kind of accident which has altered the science career upon which they set out. Some do turn to the literature of administration for information, once they have taken an administrative post, and an increasing number of younger men undergo formal research management training, but they tend to trust common sense and their "feel" for research administration. Their natural abilities, particularly their knowledge of people and their research background, seem to them the most important qualities. They administer "by doing." Sometimes, especially at the top, they see the stark truth, that they have changed from scientist to administrator.

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[18] Evidence of a growing sense of profession among industrial research administrators, who are also former researchers, is cited by George A. W. Boehm, "Research Management: The New Executive Job," *Fortune,* 56 (October 1957), 165. In training for some professions, such as librarian, engineer, and educator, apparently there is considerable concern with the administrative future of the successful professionals. Cf. Hughes, *op. cit.,* p. 137.

[19] The strongest loyalties in the U.S. civil service have been to specific agencies and clienteles and to traditional professions or technical skill groups, rather than to public administration as a profession. Cf. The American Assembly, *The Federal Government Service: Its Character, Prestige, and Problems* (New York: Graduate School of Business, Columbia University, 1954); Paul T. David and Ross Pollock, *Executives for Government; Central Issues of Federal Personnel Administration* (Washington, D.C.: Brookings, 1957).

The System and the Challenge

Is the movement of scientists within the federal service from research into research administration desirable? Are we corrupting good scientists and losing the potential fruits of their work, or are we simply recruiting administrators from the best source? Knowledge of their motives in changing and of their attitudes toward science and public administration provides groundwork for an answer.

The Research Career Opportunity

There should be reasonable opportunity for promotion for a scientist who chooses to remain within research, rather than to enter administration. This has not always been the case.[20] Some men with no special taste or talent for administration have entered it as the only way to advance to higher rank and salary. Sometimes quite good men have become involved in administration because it was their desire or the desire of their superiors that they be further honored, and only administrative posts were available to honor them. The strictly research career should always be attractively open for the man of high research talent, and even for one of moderate talent who has little administrative potentiality.

There has been encouraging movement in this direction recently in the federal civil service system. In June of 1960 the U.S. Civil Service Commission issued a "Guide for Evaluation of Positions in Basic and Applied Research." Its origins lie partly in a growing belief that the emphasis on position, rather than incumbent, has been too rigid in federal personnel administration. Two attorneys or two researchers may be doing strikingly different quality work, despite identical job descriptions. Attempts in the Department of Agriculture to promote researchers on the basis of personal attainment, without respect to supervisory responsibilities or similar factors

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[20] That scientists "all too frequently" have to take administrative assignments in order to gain promotion is attested by the former Special Assistant to the President for Science and Technology, James R. Killian, Jr., "Improving the Government's Scientific Service," U.S. Civil Service Commission, *Recruiting Scientists and Engineers for the United States Civil Service,* Report of Proceedings, Conference on Scientific Manpower, April 28–29, 1959 (Washington, D.C.: G.P.O., 1960), p. 20. Industrial research laboratories seem to have moved toward the "two ladders of promotion" principle. Cf. Boehm, *op. cit.,* p. 222; Kornhauser, *op. cit.,* pp. 135–49; Marcson, *op. cit.,* pp. 29–34. Cf. Victor A. Thompson, *Modern Organization* (New York: Knopf, 1961). The relation between specialists and general managers is central in Thompson's book. He argues for "two equal salary scales, one for specialists and one for the hierarchy."

(that is, without really changing the work they are doing) were especially influential in formulating the new program.

The Civil Service Commission guide applies only to those conducting "professionally responsible research," which includes basic and applied research, not development or testing. The guide is not intended for those who are "monitoring research contracts" or for positions emphasizing administrative responsibility; it suggests eight subordinates as a rule-of-thumb upper limit on posts emphasizing research capability rather than administrative skills. The guide "is based on the thesis that while supervision is *one ladder* to high level responsibility in scientific work, *there is another ladder* — the ladder of personal creativity and scientific contribution."

Typically in American personnel administration the job or position — the set of duties which are assigned to the occupant of the post — is central; interchangeability among incumbents is assumed; rank and pay attach to the job, regardless of who fills it or how well.[21] The new guide breaks with this idea quite explicitly, for "where the nature of the research situation involves a high potential for original and creative work, the position may be performed at any one of several levels, depending upon the level at which the incumbent is capable of working."

Four factors are to be considered in determining a researcher's grade: (1) the research situation or assignment, which focuses on the "inherent difficulty and complexity of the research problem"; (2) the supervision received, which involves the discretion enjoyed by the researcher in selecting problems and conducting investigations; (3) guidelines and originality, which pertain to the novelty of the problem, the precedents for it, and the contribution to theory or methodology; and (4) the qualifications and scientific contributions of the incumbent. An individual is awarded up to ten points for each factor, but double value for the fourth; totaling the point score, one can convert it into a grade level for the researcher. The commission has urged that rating of researchers be done within the various research agencies by panels with joint researcher-position classifier membership. Early experience in a variety of agencies has been that the scattering of ratings within a panel is not so serious as to make the system unworkable,[22] though of course a numerical rating scheme has an artificial air of precision about it.

The guide and the thinking behind it offer promise of promotion to those who remain in research posts. Only actual practice will permit us to say for each agency whether the research road or the supervisory road leads to rank and pay. Experience will show also whether the two-track system encourages the advance of second-rate men in administrative posts, where first-rate scientists may formerly have trod. It may save some first-rate researchers for research. It may enhance the morale of researchers who no longer feel that administration is the only way to agency recognition. It may make easier for scientists belief in the justness of the system within which they work.

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[21] Harold H. Leich argues that "the differences are becoming smaller in the United States and that, in many essentials, placement systems centering on rank-in-the-man and those centering on rank-in-the-job are now similar." "Rank in Man or Job? Both!" *Public Administration Review,* 20 (Spring 1960), 92. Cf. Truman G. Benedict's comment (*ibid.*, 21 (Winter 1961), 55–57), urging that rank-in-the-person should dominate, thus focusing on individual capability.

[22] Cf. H. Alan McKean *et al.*, "A Rating Scale Method for Evaluating Research Positions," *Personnel Administration,* 23 (July-August 1960), 29–36. Respecting the program in the Department of Agriculture, cf. House Committee on Appropriations, 86/2, Hearings, *Department of Agriculture Appropriations for 1961* (Washington, D.C.: G.P.O., 1960), I, 159; House Committee on Post Office and Civil Service, 86/1, Hearings, *Supergrade and Research-Scientific Positions in Various Federal Agencies,* August 20–21, 1959 (Washington, D.C.: G.P.O., 1959), pp. 3ff. Respecting the Scientist Administrator position, cf. Board of U.S. Civil Service Examiners, National Institutes of Health, "Professional Careers for Scientist Administrators in the Administration of Research and Training Grants, Awards, and Contracts in the Health Sciences," Announcement No. 227B, April 26, 1960 (Washington, D.C.: G.P.O., 1960).

The Contribution of the Administrative Choice

What are the consequences, for the individual who chooses and for the system within which he serves, of the movement from research to administration? We grant the possibility of attacking the most irritating aspect of the system, by making promotion freely available to those who remain researchers. We assume that the great majority of research administrators are not within the outstanding to near-genius class. Many of those who move into administration would not have made major and irreplaceable contributions to science through continued research.

It is impossible to judge confidently the actual value to the organization of the scientific background of these administrators, because the individual is not separable into parts. Non-scientist administrators of business-type functions (personnel officer, contract officer, budget officer, executive assistant) work within research agencies effectively, on the general assumption that they assist but do not command scientists and that they deal with business questions, not scientific questions. These distinctions are not without meaning, but they are deceptively simplified. There are even instances of non-scientists dealing with research grants, apparently effectively. A bright, immersed layman can acquire over time a startling familiarity with the language, people, and problems in an area of science, without any corresponding ability to contribute to the body of scientific knowledge. Research administrators perform functions similar to administrators in other agencies; they tend to exaggerate the differences in problem areas such as budgeting and civil service regulations. The real difference is not only that scientists do non-routine creative work, but that they believe in their work and in the reality of a community of professional colleagues.

The scientific background of research administrators may be valuable in providing technical knowledge, foresight, communication ability, and status. At a fairly low hierarchical level, the technical knowledge and skills of the supervisor are important. This is the realm of the part-time administrator who also does research. At his best, he has much of the teacher about him. As one ascends, this kind of contribution decreases. At middle levels, former researchers who are now administrators sometimes have difficulty recognizing how small their substantive scientific contribution is.

Technical competence fades into a vaguer skill in program-planning. One hears the claim that the scientist-turned-administrator can discern the opening areas, the frontiers of science. No doubt the ability to do this varies considerably, but it is difficult to accept the view that, compared with researchers, most research administrators possess special foresight into the directions that science should take. They have the advantage of an organization position which affords a useful perspective, facilitating breadth of view. However, the practicing researcher has the benefit of being personally involved in ongoing research; his own wits are sharply challenged. Presumably the former researcher might at least choose among competing views more confidently than the layman. If the administrator claims, not that he sees the future of science clearly, but that in applied research programs he is familiar with the practical needs which the program ought to be serving, the advantage of a research background is not incontestable.

A former researcher, because of his experience at science, probably understands and communicates subtleties of the scientific life. At all levels, "personnel" decisions — when to hire, fire, promote, support, discipline — and the whole realm of how to influence a subordinate to do something, are of major importance. Here one's background in science is useful in understanding the *modus operandi* of scientists in a research organization, especially what uses of authority are legitimate. Common professional background is often confused, however, with experience within a particular agency and understanding of its procedures and customs, which a layman can acquire. A scrupulous layman may learn what a superior can appropriately tell a subordinate in a research agency without destroying the loyalty, dignity, and usefulness of the subordinate. Despite their background, not all former researchers recognize the proper limits to authority.

Researchers demand scientists as superiors. In the line of command at all levels in research agencies, the symbolic value of scientists is great. The respect in which they are held as fellow scientists, rather than mere bureaucrats, transforms authority into something more than brute strength. It is not unknown for a research administrator to say that his management aides may pass favorable decisions to researchers, but that only he will tell his subordinates bad news.[23] However dubious the more strident claims of value for technical knowledge, program-planning ability, and sensitivity to the way scientists think, the elements of truth in them and the symbolic value of scientists as administrators are important. There are ample opportunities for using non-scientists in research administration, especially in staff and auxiliary positions, but we will continue to require former and part-time researchers who will take administrative posts.[24]

If the research ladder to promotion remains open, there seems no reason to deplore the movement of some scientists in truly voluntary manner into administration. (We assume that the alternative is not the abolition of administrative posts, but the use of non-scientists in them.) It serves a useful function for scientists who, despite their training and experience, are not finding much satisfaction in research. It serves a need in scientists with great drives to hold power. It permits scientists with a vision involving large resources to attempt to organize toward its achievement. It supplies research administrators who have a background and reputation in research and in government and in the particular agency or area of work. The movement of some researchers into administrative posts is not a bad thing for the individuals involved or for society.[25]

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[23] However, cf. Norman Kaplan, "The Role of the Research Administrator," *Administrative Science Quarterly,* 4 (June 1959), 28, 33. By "research administrator" he means a management official, not a scientist-administrator. He reports instances of making this business administrator the scapegoat for unpopular decisions which the scientific director actually has made.

[24] Cf. House Committee on Appropriations, 86/2, Hearings, *Departments of Labor and Health, Education, and Welfare Appropriations for 1961, Department of Health, Education, and Welfare (Public Health Service)* (Washington, D.C.: G.P.O., 1960), p. 20, Surgeon General Burney's view that a mental hospital should be headed by a psychiatrist, rather than a lay administrator, because the whole environment of the hospital is important to rehabilitation. James L. McCamy deplores the myth that scientists and science are different from other men and functions, and criticizes the separation of science from policy-making; they should be joined in government for all functions at all levels. *Science and Public Administration* (University, Ala.: University of Alabama Press, 1960), especially pp. 82ff. He insists, accordingly, though briefly, that administrators for science should be chosen without respect to whether they are scientists, simply on their ability as administrators (pp. 115–16). Scientists often are without skill in sensing social values, so lacking in administrative talent, he suggests (pp. 172f.).

Corruption

The greatest danger in converting researchers into administrators is the danger to the individual scientist. Non-scientist academicians often assume that scientists have fallen into arrogance, because of their superb techniques, their elegant and comprehensive theory, their great accomplishments in league with technology. Public statements by scientists who speak upon political and international affairs are frequently not reassuring of the scientist's sense of his limits. However, the scientist-administrators to whom this writer spoke were seldom marked by arrogance toward politics. (It is true that the group was composed rather heavily of biologists, who are reputed to be more moderate than physicists.) They were generally humble about their range of knowledge and their possible contribution to national and world affairs. Mostly they were political and administrative realists; theirs was the creed of the administrator, not of the scientist.

The scientist manages well the transition from researcher to administrator. He is not too utopian or too involved in scientific research to learn the art of public administration. As public administrator he develops skills in coping with political and administrative problems, in handling power. He deals with administrative superiors and subordinates, budget officers, administrators in allied and competing agencies within and outside government, interest-group leaders, and sometimes congressmen and political officials. Fingering its tools, he learns to value power as the means to varied ends.

Serving as administrator enhances the political and administrative understanding of the scientist, but he loses something. The scientist-turned-administrator cuts his ties to the disciplining experience, the personal responsibility, of specialization, research, and professional discourse. While becoming a political and administrative sophisticate, he may become less wise in matters close to the heart of science. He may give in to an expansive feeling of guiding the growth of science, playing the architect, without actually making any substantive contribution to it.[26] He may treat his subordinates as only means to ends which he defines. These are the sins of pride, and temptation to them always accompanies the holding of power. The danger in scientists becoming administrators is the danger in any man's taking power; scientists, too, are corruptible.

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[25] Cf. my discussion, "A Public Place for American Science," *Virginia Quarterly Review,* 37 (Summer 1961), 398–413. However, cf. William D. Carey, "Research, Public Policy, and Public Administration," *Public Administration Review,* 9 (Winter 1949), 53–63. He warns (p. 60) that "we are following the shortsighted policy of bleeding the laboratories of their skills," and suggests (p. 62) that we should "free the scientist for the work which he is most capable of doing by staffing administrative posts with nonscientist personnel oriented in the theory and practice of administration for research." Cf. Don K. Price, *Government and Science; Their Dynamic Relation in American Democracy* (New York: New York University Press, 1954), pp. 185 ff., 202, arguing for scientists in administration because of need for men with scientific knowledge plus administrative ability in solving certain kinds of policy problems. C. P. Snow urges scientists within government because they possess foresight, whereas professional (British) government administrators tend to short-term thinking. *Science and Government* (Cambridge: Harvard University Press, 1961), pp. 82f. In his Postscript, he emphasizes the need for practical judgment in scientists who give advice and the danger of having only one scientist to speak among non-scientists.

The challenge for the scientist-turned-administrator is to nourish within his agency the search for truth, rather than for power, to foster reverence for honest science. Many a factory worker or white-collar worker finds his job hopelessly unchallenging and degrading.[27] The scientist, though he too works within bureaucracy, may find his work rewarding and his environment stimulating. Because his job is not inherently absurd, much depends upon the organization within which he works.[28] No task is harder for the research administrator than to convey to his subordinates the belief that in this agency the ideals of the good scientist still predominate, that truth is respected, that administrative and political talent is the servant, not the master, of scientific talent. Bureaucracy breeds cynicism about human purposes and about the reasons for success. The scientist-turned-administrator is challenged continuously to prove to his subordinates that justice, not expediency and chance, underlies the system. He needs humility, even "one touch of regret — not the canny substitute but the true regret from the heart," [29] by which to atone to his scientist colleagues, subordinates now, for having left research to claim the prizes of power.

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[26] For the figure of speech, and a statement by a research administrator who sensed the need for restraint, cf. Roger D. Reid, "Freedom and Finance in Research," *American Scientist,* 41 (April 1953), 286–92.

[27] Cf. Chris Argyris, *Personality and Organization; The Conflict Between System and the Individual* (New York: Harper, 1957); C. Wright Mills, *White Collar; The American Middle Classes* (New York: Oxford University Press, 1951).

[28] Cf. Committee on Engineers and Scientists for Federal Government Programs, *Summary Report of Survey of Attitudes of Scientists and Engineers in Government and Industry* (Washington, D.C.: G.P.O., 1957). "Integrity of management" seemed to be of great importance to scientists in both government and industry. Cf. Howard Baumgartel, "Leadership Style as a Variable in Research Administration," *Administrative Science Quarterly,* 2 (December 1957), 344–60. He suggests that "more effective performance and more personal satisfaction" can be attained through "participatory" leadership than through "directive" or "laissez faire" leadership. Cf. Marcson, *op. cit.,* pp. 121–44, respecting the possibilities of mixing "colleague authority" with "executive authority." For a personal insight respecting the academic parallel, cf. *From Max Weber: Essays in Sociology,* trans. H. H. Gerth and C. Wright Mills (New York: Oxford University Press, 1946), p. 134.

[29] The phrase is E. M. Forster's, for a quality in a colonial administrator which "would have made him a different man, and the British Empire a different institution." *A Passage to India* (New York: Penguin Books, 1946), p. 42.

FEDERAL RESEARCH AND DEVELOPMENT FUNDING AND AMERICAN HIGHER EDUCATION

(Mr. ASHLEY (at the request of Mr. BOGGS) was granted permission to extend his remarks at this point in the RECORD and to include extraneous matter.)

Mr. ASHLEY. Mr. Speaker, Mr. Leo S. Tonkin, former associate counsel of the House Select Committee on Government Research and now executive director of District of Columbia Council on Higher Education, recently made a highly informative address before the Society of the Sigma Si, a national society composed of scientists and engineers devoted to scientific research. The speech was made at the Rolla campus of the University of Missouri. Mr. Tonkin's remarks concerned the scope and impact of Federal research and development expenditures on American colleges and universities. This is a topic of first importance to this House and the entire Nation. I am pleased to include in the RECORD a copy of Mr. Tonkin's thought-provoking and timely remarks:

FEDERAL RESEARCH AND DEVELOPMENT FUNDING AND AMERICAN HIGHER EDUCATION

Government research and development funds have become one of the largest sources of revenue to our Nation's colleges and universities. Educational institutions now receive about 12 percent of all Federal research and development funds. In fiscal year 1966, this percentage will equal approximately $1.938 billion of the total Federal research and development expenditure of $15.5 billion.

This $2 billion figure constitutes 15 percent of all expenditures in U.S. colleges and universities and fully 75 percent of the expenditures for research in those institutions.

Some 70 percent of educational funding will follow the route of project grant and contract research with the remaining 30 percent earmarked for research centers administered by the institutions under Government contract. These university research centers will receive an estimated $587,900,000 in Federal funds during the present fiscal year (1966).

Total research expenditures of the Government in fiscal year 1966 will equal an estimated $5.6 billion. Of this figure, basic research will account for $2 billion with 46 percent of that basic research budget—$952,265,000—slated for institutions of higher learning.

As with any large Federal expenditure, criticism and comment are raised. With respect to university research, a growing critical interest has brought acute awareness to the Congress that it has an important responsibility for supervision and incisive study of Federal research programs.

With such a vast and complex subject and in such a few short months, obviously, several committees have been unable to suggest fruitful solutions to all of the problems under consideration. But the hearings and reports have specified areas where better coordination and planning are recommended, and where further study of the larger and thornier issues is needed.

My remarks this evening will be addressed to an initial analysis of some of these issues, that bear directly on the Government-university relationship vis-a-vis the research dollar.

(*a*) Priorities and Federal involvement: As the breadth of Federal support of research has increased, it has become more and more difficult to establish criteria to define the limits of the Federal involvement.

The National Science Foundation, according to its Director, Leland J. Haworth, "decided that the cause of science could best be served by placing primary emphasis on merit and supporting competent scientists of demonstrated ability, or young scientists with a high degree of originality and potential."

Any scientific field qualifies; the projects chosen for support are those "that are most susceptible to a truly scientific approach and are fundamental in character."

Does this obligate the Federal Government to support all basic research of scientific merit? It seems to me that NSF—and indeed the whole Federal research program—is presently without useful guidelines for stopping short of that total commitment. From their testimony, many scientists and educators would welcome total support.

Many Congressmen would not. When a Member of the House rose in 1962 to complain about an $89,000 National Institute of Health grant to support a study of "behavioral cocktail parties," he was not challenging the scientific validity of the study, but questioning the appropriateness of Federal support.

In the 19th century, liberal Congressmen were guided by the criterion that Federal support should go to research "within neither the province nor the capacity of the individual or of the universities." And if their support for such research was meager, it was largely because they deemed only a limited variety of research studies as advancing the "national interest."

Clearly, we have come a long way from those narrow criteria. Today, many spokesmen for Federal support of research would defend the "behavioral cocktail parties" study because for them, the concept of "national interest" embraces "science for the sake of science." The umbrella is big enough for everybody.

Perhaps Curt Stern had this all-inclusive support version in mind when he described the scientist-investigator in these words: 'He can incessantly find delight in the discoveries made by other men; those of the past and those of his own times. And he can learn the difficult lesson that the journey itself and not only the great conquest is fulfillment of human life."

However, Dr. Alvin M. Weinberg, director of Oak Ridge National Laboratory, has succinctly said, "Society does not a priori owe the scientist, even the good scientist, support from society on grounds other than that the science is carried out competently and that it is ready for exploitation. Scientists cannot expect society to support science because scientists find it an enhancing diversion."

Two congressional committees have very recently addressed themselves to research priorities. In January, Congressman REUSS asked, "Are we matching research and development goals with national goals?" And Representative DADDARIO has recommended in strong terms that the National Science Foundation must hasten to set priorities and illuminate national science policy. I might note that streams of recent witnesses before both of these congressional committees, hardly addressed themselves to the salient issues of overall policy determination and budgetary direction. Rather, the comments reflected individual interests and academic orientation. Primarily because of limited availability of Federal research funds, more truly long-range thinking is needed from each of the major fields of scientific study. This objective overview-perusal from each of the academic disciplines must then act as the basis for cogent articulation of immediate as well as long-term goals for the Federal research and development program.

(b) Research effectiveness: Closely allied to a discussion of priorities and expenses is the matter of optimum productivity in the research program. It is vitally necessary to remember the striking limitations that work to counter the full effectiveness in the overall R. & D. commitment.

Funds are naturally limited. More important, however, highly qualified and competent scientific investigators are also in short supply as are physical facilities and technical backup personnel. The federally sponsored research program is calling forth the greatest array of talent in the history of our Nation. The future requirements for scientific manpower will be even more demanding.

Dr. Wallace Brode, a past president of the American Association for the Advancement of Science, summed up this possible "manpower shortage" when he wrote in the January 1964 issue of Science: "There is a crisis but it is one of approach to a limited supply ceiling and the need for better and more efficient education, rather than a need to produce more trained individuals. Production of more after the ceiling has been reached in the supply of qualified candidates merely means lowering the standards to create more poor scientists and engineers. Future leadership in science and technology is not to be based on numbers, but rather on improved quality of the graduate. This will require better teaching of only those who are qualified to receive instruction."

If highly competent research personnel really are in increasingly limited supply, then indeed the wisdom of funding research into "behavioral cocktail party" attitudes and "flavor of aroma components in roasted peanuts" must of necessity be challenged as meritorious of Federal support.

Dr. Weinberg also has voiced concern in this area with words seldom heard from the scientific community. "There is already evidence," he says, "that our ratios of money to men in science is too high, and that in some parts of science we have gone further more quickly than the number of really competent men can justify." Since 1950, he points out with allowances for inflation and the like, the number of Ph. D.'s in science and engineering has doubled, but expenditures for research have increased fivefold.

In the critical area of basic research, where Federal support might well be at an already dangerously low level comparatively speaking—the finest concentration of scientific talent is needed. But with the increasing talent demands from the applied sciences and development fields, coupled with a possible overall quality manpower shortage, this country might well be on the verge of shortchanging itself in the quality of its basic research programs. I can say that this is a question that will occasion the continuing attention of the Congress in the months ahead.

TEACHING MAY SUFFER

A very wise Persian proverb says that "men exist for the sake of each other; thus teach them or be tolerant with them; for a person is better unborn than untaught."

At the graduate level, research is one of the best teachers. Most science graduate students are engaged in research and are thus in close contact with professors similarly engaged. The lab in great measure is the classroom of the graduate.

The story is quite different at the undergraduate level. With research demanding more of a faculty member's hours, he naturally has less time to devote to teaching.

There are those who contend that academic distinction and productivity should not be measured by the number of hours a professor spends in the classroom, but rather by the quality of teaching. In the exceptional case, where the professor is indeed of a superlative stature and is often available to students outside the classroom, the paucity of teaching hours is of minimal significance. But it is a developing reality that research and publication have given too many in the undergraduate cadre an "exit with grace" from teaching, with no compensatory provisions, such as "better quality teaching in fewer hours," accompanying the trend.

This situation has assumed serious dimension in some colleges and universities. The loser has been the undergraduate student.

Dr. James A. Perkins, president of Cornell, notes, "The critical problem in the next 10 years is not so much one of research but one of students. The recent pattern of Federal aid is not generally directed toward instruction."

Dr. David Henry, the University of Illinois president has said, "The physical needs for education will somehow be met. It is not clear how the teaching task will get done."

Certainly research broadens the quality of any teacher. The danger lies in overemphasis. To safeguard against the teacher drain which already has afflicted too many faculties, university administrators must insist on a sensible balance of both teaching and research.

The Elliott committee was strong in its judgement: "* * * if there is a conflict that can be labeled 'teaching vs. research,' it is a problem that must be resolved not by a triumph of one over the other, but by proper balance between the two."

The Reuss subcommittee, in its October 1965 report, also had pointed words for the "teacher drain."

"Undergraduate teaching is all too frequently a thankless chore left to those unable to get research money—whether senior professors or younger assistants. In this topsy-turvy situation, the undergraduate may find that the university established mainly for his sake has no real place for him in the new scheme of things."

"The committee finds that too many scientists and engineers have been diverted over a relatively short period into research work, and too few are available for teaching. It will be necessary both to limit the requirements for research manpower over the short term and through an appropriate system of incentives, to increase the flow of qualified personnel into teaching."

A Reuss committee table showed that, in the 12-year period 1953–64, inclusive, the number of teachers (on a full-time equivalent basis) increased from 177,000 to 324,000 or only 83 percent, while enrollment more than doubled, and full-time equivalent of research workers at the same institutions more than trebled (up from 23,000 in 1953 to 71,000 in 1964).

John Fischer, editor of Harper's, places the quandary in simple perspective by asking "Is there a teacher on the faculty?" He pessimistically feels that it is unlikely "* * * that we can hope for any drastic improvement in college teaching to come from either the administration or the faculties. It will come, if at all, only as the result of outside pressure—from parents, alumni, and the students themselves."

Mr. Fischer overlooks one very important "outside pressure"; namely, the Federal Government and the Congress in particular. The Government has justifiably refrained from exerting pressures and persuasions on academic via research grants. But in this instance, Government money at times is being used to aid and abet a disturbing academic trend. Let there be no mistake, the Congress is aware of the detrimental effect that Federal research money sometimes has on undergraduate teaching. If the school, acting in concert with such groups as the American Association of University Professors, or the splendid association gathered here this evening, fail to correct the widening valley between student and professor, then the Government can and surely will attach certain unwelcome provisions to Federal research contracts.

While a college or university might feel reticent to unilaterally impose sanctions and regulations, the Congress will not have cause for similar reluctance. We are now in a period in which the universities literally are being cajoled and petitioned to "amend their teaching ways." For the sake of academic autonomy and faculty administrative prerogatives, let us hope the institutions heed the recommendations. If not, for the sake of the students and higher education, the Congress and the agencies will do the heeding.

It is here that distinguished ladies and gentlemen like yourselves can be so effective. You can recognize the need for more teachers and maximum teacher accessibility as well as more research. You can note the tenor of congressional and agency comment. You can respond to this situation by articulating a forceful policy and following a program that offers positive guarantees for the use of Federal research funds concomitant with adherence to realistic teaching schedules within your institutions. A positive and demonstrable policy in this regard, from within the academic community, would hardly go unnoticed in Washington, and most assuredly, after proper communication would aid in your efforts to secure new research grants, and Federal institutional support.

PANELS OF PEERS

In awarding Government research grants and contracts, many agencies rely on the advice of established experts and faculty scholars in selected academic disciplines. These groups have been of much benefit to the agencies in pinpointing quality research proposals and competent investigators. However, a concentration of membership on the panels has evidenced itself over the years, with the large research institutions having a most discernible head-count majority.

In citing the growth of a "panel establishment," the Elliott committee found that many agencies utilize the same panelists from the same universities time and time again A 5-year study of the National Institutes of Health indicated 49 percent of the names occurred repeatedly.

The research community, through this panel peer grouping is approaching a "closed community of excellence," patronized by the benevolent Government eye. Alvin Weinberg thus says, "The panel system is weak insofar as judge, plaintiff, and defendant are usually one and the same."

I have known of more than one instance where a very respected professor, having worked under large Government research funding for many years, has chosen to join the faculty of a smaller institution—not represented in the "panel establishment." Much faster than a spring thaw his Government research funding disappeared and his Washington receptiveness was a thing of the past.

This entire issue was cast in sharp focus when the Woolridge committee filed its 1965 report. There, a top group of experts were drawn together to report to the President on the National Institutes of Health. Of the 74 people comprising eight life science panels advising the Woolridge committee, eight were Government employees; of the remaining 66, 59 were 1963 NIH research grantees. From all 11 of the advisory panels, 38 members were listed in the 1963 edition of Roster of Members of Public Service Public Advisory Groups. These men were asked to make assessments of the output of a system of project approval in which they were intimately involved both as grantees and as member of peer review groups. Is it any wonder the Woolridge committee with the assistance of such panels, found that the best available method for awarding research grants is through procedures utilizing scientific peer judgment panels?

It is recognized that most panelists come from institutions rated excellent under established standards, such as number of doctorates awarded and faculty membership in the National Academy of Sciences. Still, even the Academy in a special report has recommended that panel membership be on a short-term, rotating basis and from a wide circle of academia. This sentiment has received strong endorsement from the Elliott and Reuss committees, and a limited change in panel membership might well be anticipated.

ACADEMIC CRITICISM AND CONGRESSIONAL RESPONSIVENESS

Many say that the Congress does not have the scientific expertise or advice to accord meaningful scrutiny to the university research and development program. This is partially true. Too often a congressional committee accords perfunctory treatment to the issues involved. Occasionally, a committee is established to do a particular research study job (e.g., Elliott select committee), but with a one-time-around survey, many schools are justifiably reticent to mobilize their administration for a large effort at the expense of considerable time and money.

Or other times standing committees and subcommittees, whose mandate is a total research and development look-see, cannot but study the academic problems disjointedly and sporadically—holding hearings and issuing reports on a particular aspect of the program now, with little or no followthrough for many months or even years.

Further complaints of legislative research perusal are directed to "nitpicking." Congressman MINSHALL, of Ohio, a member of the Appropriations Subcommittee on Independent Offices, commented on the research grants listed in the National Science Foundation's annual report filed in mid-February of 1965. He referred, somewhat sarcastically, among other things, to "fright substances and alarm reactions in mollusks, Cornell University, $11,200." And then he said, "Until I have had an opportunity to interrogate National Science Foundation witnesses, I offer no comment other than the fact that I am intrigued by the idea of taxpayers supporting studies of how mollusks react when frightened. I have always accepted 'cool as a clam' as a truism, and I question how many taxpayers appreciate having their money spent to perhaps learn otherwise."

Let it be noted, however, that this line item scrutiny—usually on "title of project" basis alone—keeps faculty investigators and agency people on their toes and alert to the sensitivities of Congress and their constituents relative to the sensible expenditures of public funds.

On the subject of committee testimony, admittedly, most of the commentary before congressional committees is from agency men—university people being extremely reticent to appear; and, if they do, are rarely critical in depth. Dr. Abelson, editor of Science has said, "The witness in questioning the wisdom of the establishment pays a price and incurs hazards. He is diverted from his professional activities. He stirs the enmity of powerful foes. He fears that reprisals may extend beyond him to his institutions. Perhaps he fears shadows, but in a day when almost all research institutions are highly dependent on Federal funds, prudence seems to dictate silence."

Institutional presidents sometimes seem the most reluctant to speak out—perhaps for fear of jeopardizing their relationships with the Federal agencies. (The same fear may muffle the criticism of federally subsidized scientists, thus stifling the efforts of the Congress to learn of inefficiencies and inadequacies that are present in the Federal research program.)

When invitations were extended by the Elliott committee to a number of influential university presidents to provide testimony on current problems in the Government-university relationship, a few gave careful study to the matter and provided helpful suggestions. But some refused the invitation outright or offered empty generalities and glowing platitudes, or gave the committee what it needed least; less than candid expressions of immediate self-interest, cloaked in the familiar altruistic rhetoric of science and education.

Subsequent requests by the committee to colleges and universities for facts and figures on Federal expenditures were in many instances ignored or given perfunctory attention—often, it must be admitted, because the institution did not keep adequate track of where the Federal funds were going.

Faced with these realities, strong attention should be focused on how to insure a steady flow of critical and knowledgeable commentary from the university campus. Constructive criticism is vital to a more productive Federal research program—particularly if offered by the investigators themselves. Don Price, dean of Harvard's Graduate School of public Administration and the new president of the AAAS, in noting the need for more critical comment from the scientific community, says, "Even as dissenters, they must be established, and the future status of their estate must be developed with care if we are to adjust our constitutional system to modern technology without losing our freedom."

And Logan Wilson of the American Council on Education has well summarized the concurrent responsibilities of academicians and Government officers: "Each institution should have its own sense of public mission, of course, but my own conviction is that the educational community has a right and a responsibility to share with the Government in the determination of policies and directions, that will, as much as any other factor, shape our whole future.

FEDERAL CONTRACT RESEARCH CENTERS

Under a usual cloak of Washington-imposed secrecy, some 20 or so Federal contract research centers—university affiliated though usually physically distant from the campus proper—perform complex, mission-oriented research and development work for the Government. The atmosphere is devoid of more than a dozen or so student assistants (if that) and reflects open chagrin at the idea of visitations by the centers researchers to campus classrooms and labs.

One fact stands dominant; namely, the heavy concentration of Federal research funds at these installations. In fiscal year 1966, almost $6 billion will be spent by the Government at "captive labs." One result of this funding is that the academic institutions sponsoring the facilities are usually considered the recipients of the money in general. Nothing could be further from the truth. In fact, the universities proper rarely see any of the money, or, too often even the research results. Where labs are found, a closer examination of university accounts will invariably show high laboratory funding, with the main campus receiving a much more balanced and proportional share of the total Federal research allocation. This fact should be well remembered in any "geographic dispersion of funds" discussion and the side issue of the haves versus the have-nots in university research.

For example, according to figures just released by the Reuss subcommittee on research, Johns Hopkins University was the third largest recipient of Federal funds for all university research conducted in fiscal year 1964. In that year, Hopkins received somewhat in excess of $70 million from the Federal agencies—but $55 million of that total was from the Department of Defense alone. And virtually all of that money was earmarked for the Hopkins Applied Physics Lab in Silver Spring, Md., many miles distant from the Homewood campus in Baltimore.

Not a few university presidents with captive labs located at their schools continually insist before congressional committees that the centers are indeed part of their institutions' educational missions and thus should be retained. But, the affiliation all too often appears as a tortured one, necessitating a good deal of stretch to the imagination. Nevertheless, the centers do perform a vital service at a splendid level of productivity. The labs undoubtedly assist their parent institution in such matters as prestige and drawing power on the academic professions and student interest.

Also remember that the labs perform a good deal of applied research, an area underfunded according to people such as Drs. Teller and Kantrowitz. It is clear that the contract research centers have a continuing mission for the future. It remains for the academic community to secure a better assimilation of the work of these labs into the educational mission of the universities.

SCIENCE VERSUS EDUCATION

Whenever possible, research money should be allocated in such a way that it also will do the greatest good educationally. If two institutions or two investigators have the same competence to perform a given piece of research then the choice ought to go to the one with the greater capacity and willingness to involve students in the research experience. But it is quite another thing to compromise the research investment in pursuit of an educational objective.

This research compromise now reaches beyond questionable investigator subsidization, and is transferring research funds into a catchall category of curriculums and institutional development grants. The expanding effort to build new academic centers, to improve departments, and to expand institutional capacity should be labeled properly as an academic development program—certainly not one of research. Thus, our national research program, as presently evolving in higher education, should in reality be two mutually sustaining programs—one, a constantly expanding research effort, conditioned on excellence and productivity; and the other, an institutional development program geared to future increases in graduate education and research operations.

The National Science Foundation Board in a 1958 statement—as pertinent today as then—wisely noted that, "Problems of Government-university relationships in the Federal support of research at colleges and universities should be explicitly and completely disassociated from the budgeting needs and cries of the institutions and from the general issue of Federal aid to higher education. In the consideration of these relationships there should be no implication that Federal sponsorship of research is a convenient subterfuge for Federal aid to institutions of higher learning."

In the field of academic development there are already excellent programs carried on by such agencies as the National Science Foundation, National Institutes of Health, and National Aeronautics and Space Administration which embrace open ended, Federal assistance to expand, in quantity and quality, institutions and science departments within those schools. In addition, the Higher Education Facilities Act of 1963 has just completed its first full year of operation. The results show almost $300 million expended in the 12 months of fiscal year 1965 on undergraduate and graduate facilities development. The great bulk of this amount was allocated for institutional science building construction—bricks and mortar assistance which will enable schools to command legitimate approbation of agency research distributors in the future.

Unfortunately, there is a growing diffusion of intent with reference to the dual mandate of the Federal Government in the areas of institutional development and of academic research. In a September 1965 statement to the Cabinet, President Johnson stated that, "Research supported to further agency missions should be administered not only with a view to producing specific results, but also with the view to strengthening academic institutions and increasing the number of institutions capable of performing research of the highest quality." Here the President is speaking of the research dollar doing two jobs—mission project study and academic development.

In a paper by NASA's Thomas Murphy and Thomas Adams, delivered to the 1965 annual meeting of the American Political Science Association, the writers stated this resultant dilemma:

"Can a mission-oriented agency use geography as a criterion in awarding grants, recognizing full well that it concomitantly will sacrifice time, quality, and money in the process? When grants are given to one institution on grounds other than merit, there is little basis for denying similar grants to other universities which would not normally merit them."

I submit that the development activity referred to by Murphy and Adams, might well lodge in any of the agencies commissioned to perform research. However, development programs should be clearly labeled as such and submitted to the Congress for consideration and approval. The relevant congressional committee should have full information on proposals and recommendations in both important areas of academic research and institutional development. Only in this way can legitimate priorities be established together with a Government-wide program of expanding quality research, and an increase in institutions capable of performing that research.

We cannot permit a continuation of the current ambiguity of interest. The wisest expenditure of the important research dollar lies in the balance. Both research and academic development are necessary, and at usually the same time—but can one research fund do both jobs? Too often, when attention is directed to research programs, commentators are talking in terms of Federal construction, geographical dispersion of funds for academic development, or student assistance and traineeship programs for future research expertise. Admittedly, all these programs ultimately lead to more research, but the limited research dollar cannot be the elixir vitae for comprehensive higher education advancement.

It is certainly a laudatory objective to develop new academic centers of research and scholarly proficiency. More colleges and universities with the "superlative" label attached are certainly needed. But to build such schools with Federal project research dollars would not only jeopardize at least for the present, the overall research program, but would put second-rank universities on a dangerous "easy street" to institutional expansion. It might well be noted that schools such as Johns Hopkins and Harvard did not attain their present excellence by way of Federal dollars; rather they achieved a preeminent position in education which in turn prompted the flow of Federal funds for research.

As a case in point, we have here at the University of Missouri, an excellent institution of higher learning. The student body is large and growing, the proliferation of campuses is noteworthy, the array of talent and productivity is increasingly impressive. It is a school such as this that might well wish to increase its funded research, bearing in mind the existing caveats on too much research vis-a-vis the academic mission of the institution.

There is something of the "chicken or egg" dilemma here, however. Should the University of Missouri set priority sights on more research dollars or on academic improvement and development programs first, which in time would garner the desired increment in funded research? A marvelous program, ideally suited to the University of Missouri and one that I am sure is already known by this institution, is the science development grants program of the NSF. Under its provisions very large open-ended grants are annually awarded to academic institutions that are not now among the very foremost in science but that have substantial present strength and, in addition, have shown sound planning for future improvement.

Many in Washington speak of the need for new academic centers of excellence. This NSF program is one important way to meet that need. And yet, the President's new budget, while recommending a substantial increase in funds for the National Science Foundation, has only a $5 million increase to a $45 million total, over last year's budget figure. Unfortuntely, for a program which commands such widely voiced support from all quarters, it is most discouraging that it fails to receive larger funding. I would suggest that budgeting for vital science development programs such as this might well command your close attention and comment over the months ahead to Washington.

This, then, is the state of Government support of university research today. The work of the Congress over the past year has been accompanied by a restrained and reasoned approach to the questions and problems that surround our national research program. The fear that Congress is about to curtail its support of research or stifle the efforts of the Nation's deserving scientists, or turn its back on the many problems of higher education is wholly without foundation.

Seemingly, the most obvious requirement on the part of the academic and scientific community would be an articulate form of response, recognizing research program modification as inevitable and healthy, and embracing constructive, specific suggestions for changes best serving the Nation's interest, and the institutions educational mandate. You might well disagree with some of my comments this evening, but do have a capacious and vocal interest in all of them.

Naturally, there are difficulties in the Federal research program and the situation promises continuing concern over the months ahead. During this time of reappraisal and program modification, one fact is clear—if institutions are to maintain the educational ideals and traditional autonomy in conjunction with strengthened research activity, then the major advances in this Government-university partnership must be premised on clearly defined educational philosophy and sound institutional organization.

In order to clearly articulate and define a campus research policy, those responsible for our institutions of higher learning must take a more active role in the decisionmaking processes involving Federal funds. They must be aware of the changing Washington spirit, and they must know how to plead their cause before the Congress. They, and indeed you, should be totally aware of the issues I have mentioned this evening. Know of their impact on the research programs, and participate in the dialog that swirls about these questions, particularly in Washington.

If solutions are to be found for many of the imbalances and inequities in the campus-Government research partnerships, the solutions most properly should be proffered from within the academic community. Welcome this responsibility. Develop your suggestions, suggestions for change, where warranted, and suggestions for maintenance of policy where desired.

Above all, take part in the discussions that call your opinions to Washington and take part not on a sporadic or disjointed basis but with firm, concerted effort on behalf of your particular disciplines and as spokesmen of the academic community.

Now you might well ask, How can you suggest we criticize the agency that supports us, or the programs under which we have applied for funds? But my friends, it is not a reliance on criticism that I am recommending, but rather positive and constructive commentary on your part. Believe me, ladies and gentlemen, the Congress will respond with alacrity to your challenge for excellence.

Certainly research continues to be the key to national growth and security. This vibrant, scientifically oriented era of the mid-20th century might well be termed the research years—a time when an evergrowing portion of our physical human resources is being diverted into the unknown and then turning raw discovery into great technological achievements for man's benefit. It has become a matter of common faith that much greater advancement is yet to come.

Indeed, no one has summarized the spirit and vibrance of the research years more eloquently than Ernest Hemingway, when he said, "We are living in the morning of an epoch, and in the fog of the early dawn men walk confused and see strange sights. But the fog will melt under the rays of the very sun which has created it, and the world of truth will be seen to be solid and lovely again. All the glory of life, all the romance of living, all the deep and true joys of the world, all the splendor and the mystery are within our reach."

2. Leadership in science policy

In section 3(a)(1) of the National Science Foundation Act of 1950, Congress made it a responsibility of the Foundation "* * * to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences." As seen in chapter II, this responsibility was changed by Reorganization Plan No. 2 of 1962 which transferred a vaguely defined part of this responsibility to the Director of the newly established Office of Science and Technology. Specifically, the plan transferred to OST—

> So much of the functions conferred upon the Foundation by the provisions of section 3(a)(1) of the National Science Foundation Act of 1950 * * * as will enable the Director to advise and assist the President in achieving coordinated Federal policies for the promotion of basic research and education in the sciences.

Although Dr. Hornig and Dr. Haworth were careful in their testimony to say how this responsibility for a national policy for basic research and science education was divided between their offices, the division of this responsibility in practice still seems unclear. There appears to be no consistent pattern of leadership for formulation of Federal science policy. Leadership can come from any direction within the Federal organization for science and technology and does not seem to be strongly identified with the Foundation. The NSF appears more to react to evolving changes in the interests of the scientific community than to take the initiative to influence and shape such changes to national needs. As the one agency within the Federal establishment concerned with the health of national resources for science and technology, and the means of fostering science and scientific capabilities, it would appear that the Foundation's voice in these areas should be carefully considered. The Foundation has the potential capability to influence the ways in which other Federal departments and agencies employ science and technology in furtherance of their mission objectives while at the same time strengthening the scientific and technological resources of the Nation.

With this in mind, it is useful to briefly examine the Federal superstructure for science and technology.

(*a*) *The Federal superstructure for science and technology*

The appearance of a superstructure for Federal science and technology as an aid to Presidential decisionmaking has been fairly recent. From the end of World War II to just before the Soviet Union launched

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[44] *Ibid.*, letter of Dr. Handler, question 2, p. 1418.

Sputnik in 1957, the only formally constituted bodies to advise the President on science were the National Academy of Sciences and a relatively obscure Science Advisory Committee in the old Office of Defense Mobilization. Eight years later one finds that the President has acquired four new sources of advice and assistance for science and technology, in addition to the National Academy of Sciences. The testimony received by the subcommittee contains much information and insight into the organization, functions and interrelations of these sources. For the purposes of this discussion, the following features should be noted:

(1) *The President's Special Assistant for Science and Technology.*—Shortly after Sputnik, President Eisenhower created the top-level post of Presidential Science Adviser and assigned to it the task of taking stock of the Nation's scientific and technical resources, and the devising of ways to bolster and mobilize these resources to meet this new Soviet competition. The science adviser serves in a confidential capacity to the President and because of executive privilege, cannot be summoned to appear before the Congress.

(2) *The President's Science Advisory Committee.*—While the old Science Advisory Committee of the Office of Defense Mobilization did not report directly to the President, it did have the function of advising him, through the Director of the ODM, about scientific research and development for national defense. In December 1957, President Eisenhower transferred this Science Advisory Committee from the ODM to his office, making it directly advisory to the President and enlarging its membership—which increased its stature, power and appeal to the scientific community. The President's Science Advisory Committee is composed of his Special Assistant for Science and Technology and others of the Nation's most distinguished scientists and engineers, drawn from industry, the universities and other parts of the scientific and technological community. Its Chairman is elected by the Committee and, by custom, is the President's Special Assistant for Science and Technology.[46] The President appoints its members for terms of 4 years. PSAC meets about 2 days a month and is concerned with major issues bearing upon the country's scientific and technological condition. It undertakes studies both on its own initiative and in response to requests from the President.

The PSAC is aided in its work by many panels of experts drawn from the scientific and engineering communities. Individual PSAC members contribute substantially of their time as panel members. Although these bring together many leaders of science and technology to advise the Government, the panels are temporary and have no responsibility for following through on implementation of their recommendations.

(3) *The Federal Council for Science and Technology* was created by Executive Order 10807 of March 13, 1959. Its function is to promote closer cooperation among Federal agencies and coordination for the total Federal effort in science and technology. Composed of top policy-level representatives from each of the Federal agencies involved in science and technology, it provides a two-way link between these policy level officials and the President and his office. It also has served to tighten White House control over scientific programs and policies of the Federal agencies, establishing a new path for Presidential

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[46] For current membership of PSAC see Hearings, p. 103.

influence in parallel to the path already established through the Bureau of the Budget. The subcommittee notes that some confusion persists concerning the combining of the chairmanship of the Federal Council, the directorship of the OST and personal scientific advice to the President in one individual. It is not clear to what extent Dr. Hornig serving in these multiple capacities is free to answer congressional questions. The subcommittee notes that he chairs the Federal Council not as the Director of OST—who is accessible to the Congress—but as science adviser to the President, who serves in a privileged position.

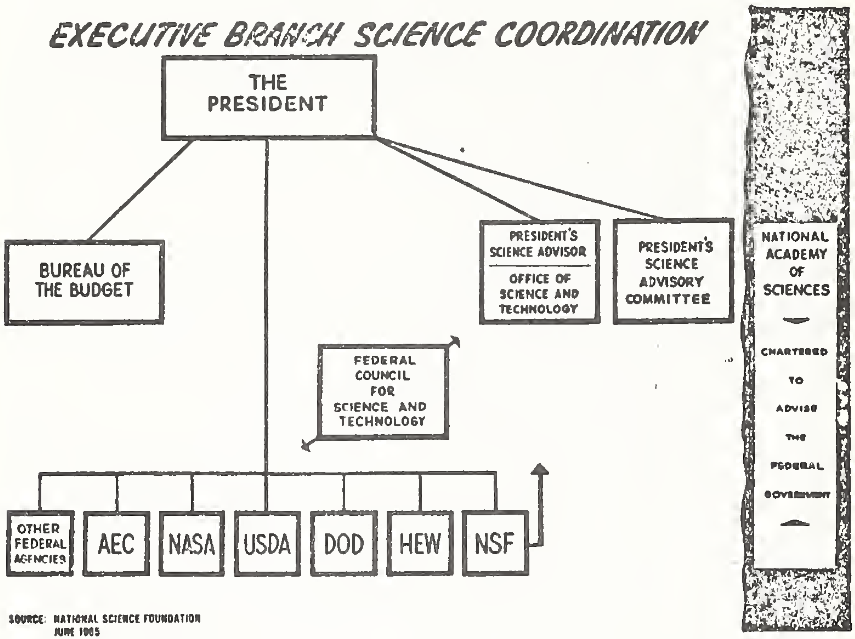
Selected scientific and technological activities common to a number of agencies are coordinated through a series of interagency committees, including those on Oceanography, Atmospheric Sciences, Materials Research and Development, High Energy Physics, Water Resources Research, Behavioral Science, Patent Policy, Long Range Planning, International Programs, Science Information, Scientific and Technical Personnel, and a standing committee concerned with the operations of Federal laboratories. The Council Secretariat is provided by the Office of Science and Technology.

(4) *The Office of Science and Technology* completed the present framework of the Federal superstructure for science. It was established, with congressional accedence, by President Kennedy's Reorganization Plan No. 2 of 1962. The Director of OST is generally responsible for assisting the President in coordinating Federal science and technology functions. In essence, the OST did not represent so much a new scientific function for the Executive Office of the President as it did a formalizing of already existing functions.

The establishing of the OST may also be viewed as a response of the administration to congressional unrest over the lack of coordination and central control of the Government's expanding research and development. It provided Congress with a single spokesman to answer questions about the administration's plans and policies for Federal science and technology, a function that the previous Science Adviser could not fully perform because of his confidential relationship to the President. This separation of the role of the President's Special Assistant for Science and Technology from the planning and coordinating and evaluating functions of the Director of the OST appears to adequately preserve executive privilege while assuring Congress an open avenue of communication to the superstructure. However, as noted above, some possible conflict may still remain as long as the Director of OST simultaneously holds the posts of Special Assistant to the President, Chairman of PSAC, and Chairman of the Federal Council. It is not entirely clear to the subcommittee what standards can be used to draw the line between information and opinion which is properly privileged, and that which should be freely available to the Congress for public debate. This uncertainty might be reduced by separating the confidential functions of the adviser from the executive functions of the Director of the OST. By assigning these posts to different men, the adviser and PSAC could concentrate upon advice to the President, especially on subjects that have to be kept secret for the national security, while the OST and the FCST could concentrate upon public policy for science and technology.

(b) *Relation of the National Science Foundation to the superstructure*

To illustrate some of the relations of the Foundation to the Federal superstructure for science, Dr. Haworth presented the chart shown in figure 3. Note the arrow leading up from the NSF which indicates that the NSF by statute has a special role over and above other agencies with respect to collecting information and suggesting policy. According to Dr. Haworth: "This simply means that NSF feeds back to the executive offices, the FCST, et cetera, the results of its studies and the suggestions that it has." [47]


EXECUTIVE BRANCH SCIENCE COORDINATION
THE PRESIDENT
BUREAU OF THE BUDGET
PRESIDENT'S SCIENCE ADVISOR
OFFICE OF SCIENCE AND TECHNOLOGY
PRESIDENT'S SCIENCE ADVISORY COMMITTEE
NATIONAL ACADEMY OF SCIENCES
CHARTERED TO ADVISE THE FEDERAL GOVERNMENT
FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY
OTHER FEDERAL AGENCIES
AEC
NASA
USDA
DOD
HEW
NSF

SOURCE: NATIONAL SCIENCE FOUNDATION
JUNE 1965

FIGURE 3

The most important relations of the Foundation to the superstructure appear to be those with the Office of Science and Technology. Dr. Hornig described these at some length and identified three special relationships: [48]

Collection of basic data: The Foundation has a central responsibility to provide basic data on science resources, on expenditures for research and development, and on scientific manpower. The data acquisition and analysis capabilities of the Foundation are utilized by the OST as a basis for the development of national science policies.

Special assignments: The Foundation can serve either as an executive agent or a delegated agent of the OST in taking the lead in certain assignments of broad importance. For example, the OST requested the Foundation to develop an interagency assessment of and reaction to the recent report of the National Academy of Sciences on needs in ground based astronomy.[49]

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[47] Hearings, p. 15.
[48] Hearings, p. 112.

Advice on science policy: According to Dr. Hornig, the Foundation is a "particularly valuable source of advice"[50] to the OST on science policies that merit consideration for Government-wide application.

Dr. Hornig also identified another relationship between the Foundation and the OST, similar to that of the Executive Office with other departments and agencies. The OST reviews and examines the programs of the Foundation in the same way it looks at those of other agencies. Because of the limited OST staff, this examination is highly selective and concentrates on items of major importance. It is concerned mainly with the directions in which the programs are tending, the opportunities that may be neglected, and major budgetary issues. The National Science Foundation also participates as a full member of the Federal Council in working out with other agencies common policies for subjects such as administration of research and development, and the level and distribution of activities for those fields of research that cut across agency programs.

Dr. Hornig called attention to major future problems which will call for stepped up efforts to develop new and improved approaches to the planning of Government programs for the support of academic research and for relating this research to the large science programs supporting particular national objectives. This, in turn, will call for even closer cooperation between the OST and the NSF.[51]

Looking at NSF relations with the President's Science Advisory Committee, these seem characterized by a trend, which might not be healthy for either.

Although PSAC's and OST's interests extend across the full range of Federal scientific and technological activities, since Reorganization Plan No. 2 they have focused considerable time and energy upon resources for science—which is a province and strength of the Foundation. As a result, PSAC and OST have not been able, on a continuing basis, to look into many important aspects of the application of science and technology to national purposes and to urgent problems of our technological civilization. Meanwhile, the Foundation's capability to pursue a national policy for basic research and science education appears noticeably inhibited.

For example, during the past summer, PSAC began a study of the criteria for distribution of Federal funds for research at universities to see how these funds might reinforce scientific excellence of existing institutions, increase the number of first rate institutions, and broaden the base of scientific research and education. The NSF is closely related to this study for it is providing the necessary staff support. Yet the only participation of the National Science Board, which is part of the Foundation, seems to have been the personal membership on the PSAC panel of four Board members. It would seem that a subject relating so directly to the state of our basic research might well receive the attention of the entire Board as a formally constituted, continuing part of the Government.

The PSAC reports dealing with scientific information and manpower are also examples of subjects relevant to national science resources that could have been examined by the Board.

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[49] It should be noted that the Foundation is usually responsive to recommendations from the National Academy of Sciences without formal endorsement of them by the OST or the Federal Council.

[50] Hearings, p. 112.

[51] Hearings, p. 116.

(c) *Problem areas*

The elaborate and intricate structure of executive branch organization for science policy formulation provides some reason for uneasiness. Coordination of Federal policy for science is splintered among a number of organizations. The present arrangements cannot help being somewhat inefficient and uncertain.

Since NSF does not fully exercise its science policy function, it has created a partial vacuum in Government affairs which is being filled by the OST and PSAC. PSAC and OST themselves are weakened and limited by concentrating so much of their time and energy in the fields of the National Science Board's interests and competence. The problem is to reassert and energize the function of the Foundation in creating and shaping a national policy for basic research and science education for the whole Government.

Despite the present and future importance of their advice and activities, neither the Federal Council for Science and Technology nor the President's Science Advisory Committee has shown a disposition to work with the Congress lacking a specific invitation. This points to the fact that important decisions of national policy may be made by groups which do not regularly appear before the Congress.

THE PRESIDENT'S SCIENCE ADVISERS

PHILIP H. ABELSON

The Role of the Adviser

TODAY and in the foreseeable future, a nation's prosperity and security depend upon the wisdom and timeliness of decisions made with respect to science and technology. The circumstances dictate that the best scientific and technical minds be consulted and that the results of their deliberations be conveyed promptly to the highest authority. Since the head of a government has a wide spectrum of responsibilities, can work closely with only a limited number of persons and is himself no expert in science and technology, it is not uncommon to maintain the post of Science Adviser and to use its incumbent as the primary source of counsel in scientific and technological matters. In the United States the President, since late 1957, has had frequent recourse to the services of a Science Adviser.

As with all human arrangements for the exercise of power there are advantages and disadvantages in concentrating authority for decision-making in one person. The office and its supporting machinery are relatively new and correctable deficiencies are to be expected. In what follows I will largely portray some negative features of the advisory complex.[1] My negative approach is due in part to the fact that it is easier for an outsider to identify failures than to specify successes. There is a paucity of positive evidence concerning the quality of performance of the President's advisers, especially the last two. The major tangible basis is a relatively thin collection of reports arising from studies conducted by panels appointed by the adviser.

As an illustration of the difficulty of identifying contributions of the Science Advisers, consider events surrounding the Nuclear Test Ban Treaty. Dr. Wiesner, who was Science Adviser at the time, was known to favour such a treaty. However, he was one among many proponents. In the important Senate hearings some 40 witnesses testified. He was not among them. Nor did he participate in the crucial negotiations at Moscow.

There is little public evidence that the adviser or his staff have addressed themselves to many major problems which might be expected to fall within the adviser's responsibility. For instance, a crucial problem is how to harness effectively the vast scientific and technological resources of the nation. Do the present allocations of money and manpower make sense? If this is too big a question, an alternative one is: do present policies of research support at times damage the national interest? Some of us believe they do.

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[1] For a favourable treatment of the adviser's role, see special report on "White House Superstructure for Science", *Chemical and Engineering News*, XLII (19 October, 1964), 42, pp. 78–92.

The advisers and their staffs have concerned themselves with many relatively trivial problems to the annoyance of some of the other parts of the government. Anyone acquainted with Washington civil servants engaged in science can learn of their discontent with the advisory system. Many such scientists have felt arrogantly mistreated by the men who have occupied the post of Science Adviser or by their agents. In what follows I will discuss the power structure available to the President's Science Adviser. I will then describe how the structure has at times functioned and make some suggestions for improvements.

The Science Adviser's authority stems from many sources. He is the President's personal science adviser, the Chairman of the President's Science Advisory Committee, the Director of the Office of Science and Technology, and the Chairman of the Federal Council on Science and Technology.

A major element in the power structure is the Office of Science and Technology. The formal objectives of the creation of this organisation can best be described by quoting directly from the President's Message to Congress of 29 March, 1962.

> . . . it is contemplated that the Director will assist the President in discharging the responsibility of the President for the proper coordination of federal science and technology functions. More particularly, it is expected that he will advise and assist the President as the President may request with respect to:
>
> (1) Major policies, plans and programs of science and technology of the various agencies of the federal government, giving appropriate emphasis to the relationship of science and technology to national security and foreign policy, and measures for furthering science and technology in the nation.
>
> (2) Assessment of selected scientific and technical developments and programs in relation to their impact on national policies.
>
> (3) Review, integration, and coordination of major federal activities in science and technology, giving due consideration to the effects of such activities on non-federal resources and institutions.
>
> (4) Assuring that good and close relations exist with the nation's scientific and engineering communities so as to further in every appropriate way their participation in strengthening science and technology in the United States and the Free World.
>
> (5) Such other matters consonant with law as may be assigned by the President to the office.

To implement an effort to coordinate research, the Science Adviser has been given major additional power. He participates in decisions on budgetary matters. In effect, he is at times director of the Bureau of the Budget where scientific matters are concerned. Such a statement could be made on the basis of conversations with government people in Washington but the matter has been described fairly clearly in an address by William D. Carey, Executive Assistant Director of the Bureau of the Budget. His statement was printed in the *Congressional Record* of 30 September, 1963, from which the following is quoted:

> The Bureau of the Budget has never agreed with suggestions that it should establish within its structure a Division of Science, staffed with qualified scientists and engineers, to review R. and D. proposals. To be sure, our analysis frequently requires input of sophisticated professional judgment as to technical feasibility, state of the art, and possible alternatives to a proposed line of development, as for example in the moon program or in the missile field. In recent years, however, we have been able to obtain this kind of judgment through the Office of Science and Technology and the President's Science Advisory Committee. This year, for example, we selected the areas of atmospheric science, oceanography, water research, high energy nuclear physics, basic science, and science information for special review, and we conducted this exercise jointly with the Office of the President's Science Adviser.

It is clear from this quotation that the Bureau of the Budget is inclined to listen to the Science Adviser's counsel on scientific matters. Should some question arise as to his rightful pre-eminence, he has at his disposal a battery of leading scientists who would be stronger than any group which the Bureau of the Budget might assemble. I need not dwell on the real power that monetary control gives. Even the most powerful agency head must worry about his budget. I know of no evidence that this budgetary power has been misused but its very existence cannot but colour relations between the adviser and various agencies of the government.

Another unofficial source of power is activity in the appointments of top-level scientific personnel. When an important post becomes vacant, the Science Adviser, among others, is consulted in filling it. In view of the various positions he formally occupies he has a considerable voice in the making of such appointments.

Adviser and the Advised

It seems evident that the Science Adviser, whoever he may be, has available an ample machinery of power. The manner in which the structure functions, however, depends crucially on human factors—among them the temperament of the President, the relations between the President and his Science Adviser and the temperament of the adviser. For instance, President Kennedy displayed considerable interest in science and the President's Science Adviser had more and easier access to Mr. Kennedy than any other scientist had. In the *New York Times* Magazine Section of 3 September, 1961, Mr. Finney has said:

> There is also a close, informal relationship between the President and the young engineer who was one of the campaign confidants and advisers. Hardly a day passes that Wiesner does not talk to the President, either in person or by telephone.

Such a relationship does not go unnoticed in Washington, where agency heads and Congressmen are sensitively attuned to nuances. Access to the President gives a man power that others respect and defer to. Close association with a President carries with it liabilities as well as assets. Presidents are usually intensely political in their outlook and they tend to react to events as they occur. In the process they urgently use whatever tools are at hand. A Science Adviser enjoying the complete confidence of a President may find himself diverted to fighting a series of minor political brush fires. He must also be responsive to any special interest, however misguided, that a President may evince in scientific or technological matters. While thus occupied, the adviser must give secondary priority to longer-term problems which may be of much greater enduring significance.

The relationship between President Johnson and his Science Adviser, Dr. Hornig, has naturally not been very close. Dr. Hornig was designated by President Kennedy and before the assassination Dr. Hornig and Vice-President Johnson had little contact. During most of 1964 the President was heading what was necessarily an interim administration. With a fresh mandate, he became free to choose his own advisers and to operate in ways that suit him best. Regardless of whom he chooses as the adviser, be it Dr. Hornig or another, a new relationship will evolve.

One factor that will shape that association will be the demands of the times. If the cold war eased further, there could be a lessening of the need of the President for an adviser. If the economy were to slow down, efforts might be made to use science and technology as a means of creating new jobs. The long-term trend is towards a larger role for science and technology in most aspects of civilisation, which is likely to lead to an increase in the importance of the role of the Science Adviser.

The mode of conduct of the Science Adviser's establishment is considerably influenced by his own personality and especially by his appetite for participating in many decisions. In the course of their activities the Science Advisers may, if they wish, make recommendations concerning a wide variety of problems.

The Adviser and his Advisers

To help him the President's Science Adviser has in addition to an operating staff the benefit of two principal advisory mechanisms. The most prestigious of these is the President's Science Advisory Committee (P.S.A.C.), of which he is chairman. This committee consists of 18 distinguished scientists who customarily meet for two days each month. In the meetings an agenda of numerous items is covered. In situations like this, a full-time chairman dominates the proceedings as far as he wishes. He can select the items that appear on the agenda. He can choose the information to be presented to the committee, and even the individuals who will perform the necessary briefings. With committees of this type it is only necessary for the chairman to be able to count on the active support of four or five of the 18 to assure effective control. Members of this committee serve for four years and are appointed by the President, who, in making appointments, naturally consults the man who is both his Science Adviser and the chairman of the committee. Even a man with moderate talents could control such a situation.

The adviser has at his disposal, if he wishes to use it, essentially the total scientific capabilities of the United States, for almost everyone will respond to a request from the executive offices of the President. The usual method of employing them involves *ad hoc* panels. As an example of how a panel might work, consider the two hypothetical questions about the National Aeronautics and Space Administration's policy with respect to scientific exploration of the moon. Should all unmanned vehicles concentrate on obtaining information relevant to the Apollo programme? Should scientific experiments be conducted that apparently have no direct relevance? To answer such hypothetical questions, a panel of scientists would be convened. The executive secretary of the group would be the man who is in charge of the space desk in the Office of Science and Technology. One or more members of the panel would be members of the President's Science Advisory Committee. Others would be distinguished scientists who had participated actively in the space programme.

There are those who might inquire as to the justification for the President's Science Adviser's participating in a policy matter so central to the activities of N.A.S.A. The answer is, of course, that lunar exploration requires money and, in turn, decisions by the Bureau of the Budget.

No official list has been published which permits complete identification of panelists, but the general composition of the panels is known, in part through the work of Miss Greenfield of *The Reporter* magazine, who spent a year studying the operations of the Science Adviser's Office. She states that "about half the mystery guests come from private industry".[2] A substantial number of the remaining half, the academic representatives, are either at present in the Cambridge area or have in the past had some connection with it, such as service in the M.I.T. Radiation Laboratory during World War II.

Actually, the panel system has serious potential weaknesses. Brilliant men come to Washington for a few days, are given detailed briefings, and then, with a limited amount of time for consideration, form opinions on matters that may involve tremendous sums of money and even the security of the nation. Their eventual recommendations can be manipulated by controlling the nature of the briefings. Their report, when issued, is in general not a public document. Thus, if it is not convenient to implement the conclusions, the report can be pigeonholed.

Advisory groups such as P.S.A.C. and the panels can be a valuable source of ideas and information but they cannot usefully make operating decisions, nor can they implement them. Since the panel members play an advisory role and since they are stationed elsewhere, they cannot be held fully responsible. They have considerable influence while at the seat of power, but once away from it, their influence diminishes.

Numerically, the 300 or so panel members who have been called upon by the adviser represent on the order of 0·01 per cent. of the nation's scientific and engineering brains. Are they our best brains? We have no way of knowing, for the identity of their owners is kept secret. Are they used effectively, or are the advice and ideas of these men circumvented? We do not know. Could the ideas involved be sharpened by suggestions and knowledge possessed by the 99·99 per cent. who are not consulted? Again, we do not know because it has not been tried.

The Adviser and his Staff

With all his duties the Science Adviser can personally attend to only a tiny fraction of the problems and developments. Although he can get much good counsel from advisory bodies, he must depend heavily on a group of full-time associates. The principal source of assistance is a staff of professional aides totalling about 16.

An official version of what this group does was presented in a statement by a former adviser on 16 October, 1963, at a hearing of a subcommittee of the House Committee on Science and Astronautics[3]:

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[2] Greenfield, M., "Science Goes to Washington", *The Reporter*, XXIX (26 September, 1963), 5, pp. 20–26. The article was reprinted in *Science*, CXLII (18 October, 1963), 3590, pp. 361–367.

[3] Statement of Dr. Jerome B. Wiesner at Hearings on Government and Science before the Subcommittee on Science, Research and Development, House Committee on Science and Astronautics, 88th Congress, First Session (16 October, 1963), pp. 58–109.

> The Office of Science and Technology, since its establishment last year, has developed into a staff mechanism to serve the Special Assistant, the P.S.A.C., and the Federal Council. Slightly more than a dozen highly trained specialists in science, engineering and administration provide assistance to these activities by identifying issues, phrasing questions, gathering information from the agencies on problems in scientific fields, working closely with the Bureau of the Budget, the Council of Economic Advisers, and other Executive Office agencies, and following up the implementation of federal programs. In addition, the Office has served as the channel by which the Executive Branch meets its duties to the Congress on matters of over-all science policy.

That the Office of Science and Technology staff has large responsibilities and authority is indicated in the phrase " following up the implementation of federal programs ". One would expect this staff to be of the highest professional calibre. I was, therefore, interested during October 1963 in checking up on the qualifications of this group of so-called " highly trained specialists ". Although a few were found to be competent, they did not in sum constitute a distinguished group of scientists. A search of *Chemical Abstracts* and *Science Abstracts* revealed that during the past 10 years few of the 16 men had written for any of the publications abstracted by these services.

Nevertheless, this group collectively has exercised perhaps almost as much power as the adviser. Some of the mechanisms by which power has been exerted have proved distressing to government agency heads. For example, the director of a great national establishment, often a man of outstanding scientific stature, might receive a telephone call. The voice at the other end would say: " This is the White House calling ". The director was faced with a dilemma. Whom did the call represent? Was the Science Adviser's Office calling to pass on an order from the President, or the President's Science Adviser, or the Chairman of the President's Science Advisory Committee, or the Director of the Office of Science and Technology, or the *de facto* Chief of the Bureau of the Budget? Or was the staff member from the Office of Science and Technology who was making the call simply throwing his weight around? In the past the last has often been the right interpretation but the agency head felt well advised not to question too closely, even though he might suspect that he was being bullied by a minor member of the staff. Not infrequently the call was a request for charts and information to be used in a briefing the next day. The director had no alternative but to turn his agency upside down to meet the deadline. If the President or the Science Adviser were personally interested in the material and he failed to deliver, he might find himself in a highly embarrassing position.

On a number of occasions I have been in touch directly and indirectly with many of the major agencies in Washington. Almost all have had numerous calls from staff members in the adviser's office. It was not always the agency head to whom the request was directed. I am told that members of the staff of the Office of Science and Technology have seen fit to communicate with subordinates within agencies, sometimes without the knowledge of the responsible head. This kind of procedure can wreak havoc with morale, for when it occurs, the underlings often assume that their chief is on the decline.

About a year ago, in talking with a man relatively high up in the Space Administration, I elicited the information that the man who has the space desk at the Office of Science and Technology was in frequent communication with various subordinates in the Space Administration and that he often concerned himself with technical matters. N.A.S.A. has attempted to obtain the advice of the scientific community and for this purpose has a number of advisory groups whose membership includes Nobel Prize winners, many members of the National Academy of Sciences and most of the leading contributors to space research, such as Professor James A. Van Allen. The total membership of these advisory subcommittees is about 70. In an effort to assess the weight their advice carries, I asked the official this question: " Would you say that an underling in the Office of Science and Technology has more weight in technical decisions affecting the Space Agency than that possessed collectively by all your consultants?" The reply was, " Yes, he does." The official in question is a conscientious person, and I would not wish to seem to disparage his character or accomplishments. But the fact is that he has not demonstrated unusual proficiency in the area in which he wields so much authority.

According to the original plan, staff members of the Office of Science and Technology were to act as subordinates, making arrangements for panels and acting as go-betweens in the transmission of information from the adviser and the President's Scientific Advisory Committee to the agencies. In practice, however, P.S.A.C. and the panel members are on hand only a small part of the time. The adviser is engaged in hundreds of activities. Someone must make interim decisions and the responsibility naturally falls to the staff of the Office of Science and Technology. Thus, in reality, though it was not planned that way, a major fraction of government research policy is made and executed by a small group of men having little proven eminence or even competence in science.

The Adviser's Jurisdiction

My impression is that many of the unsatisfactory features of the adviser's conduct of his office in the past have arisen from the attempt to deal with too many of the wrong kinds of problems. It would be far better to do a few supremely important tasks well than to be immersed in a bottomless morass of petty detail. There are important situations which from their very nature must be handled at the top level. Matters like the nuclear test ban and first-rank military questions encompassing sophisticated science and technology probably must be dealt with at the highest level. Then there are issues such as that raised by Rachel Carson's *Silent Spring*[4]; if only for political reasons, a President would feel obliged to employ high-level advice in making a response to the furore raised by such a book.

There are other problems with which the Science Adviser should grapple and for which his office is uniquely fitted. Problems involving long-term planning are an example. In the United States remarkably little attention has been given to the future and to the consequences of contemporary activities. For instance, our research grants system is profoundly affecting higher education, probably adversely, yet the trends go almost unnoticed.

Another class of problems are those transcending the competence or jurisdiction of any existing arm of government and requiring the ultimate establishment of new mechanisms. A good example is the need that arose for a new agency to take jurisdiction over space matters. The first Science Adviser, Dr. Killian, was instrumental in the creation of the National Aeronautics and Space Administration.

The present structure of the adviser's office has at least one glaring defect, which is a consequence of the formal objectives of the Office of Science and Technology quoted earlier. Some of the relevant phrases include: " the Director [Science Adviser] will assist the President in . . . the proper coordination of federal science and technology functions. . . . he will advise and assist . . . with respect to . . . (3) Review, integration and coordination of major federal activities in science and technology . . . ".

The periodic review of major programmes can be extremely useful, provided that such examinations are conducted in depth, with elaborate care and due dignity. The best brains of the nation can be recruited for such a task. This is the kind of effort the scope of which can be delineated precisely and the proceedings can lead to greater effectiveness in relevant agencies and at times to the initiation of new procedures or even to useful legislation.

In contrast the words " integration and coordination " carry with them no end of mischief. In their present context, the words are fuzzy, even utopian, in connotation. It is literally impossible to coordinate perfectly the activities of two creative scientists—let alone thousands. Thus the Office of Science and Technology is chartered to perform a task that can be neither sharply delineated nor actually accomplished. Moreover, since new developments are always occurring, the unattainable goal changes constantly.

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[4] (New York: Houghton Mifflin Co., 1962; London: Hamish Hamilton, 1963.)

In the long pull the best brains of the nation are too astute to be trapped into such an undertaking. If " integration and coordination " are to be performed by the Office of Science and Technology the burden must rest with the limited staff of the office.

On 22 November, 1963, there appeared in *Science* an editorial written by myself which seems to have continuing validity, and which may serve as a conclusion to the foregoing reflections on the problems of organising the system of scientific advice in the United States:

> In his many roles Wiesner has been required to present at least three differing visages to the world. As the President's adviser, his appropriate function has been that of self-effacing, impartial judge, often acting under tightest security. As director of O.S.T., it has been in the public interest for him to wield authority as openly as possible. His power also implicitly has required him to be a statesman of science—a deep thinker—with long-term views of evolving patterns in science and technology and of the relations among society, science, and education.
>
> The realities of politics and power dictate that the role of President's Science Adviser and its needs should transcend all other functions. Almost inevitably the secrecy necessary to that office has been carried over into the Office of Science and Technology, which attempts to keep secret even the identity of its . . . consultants. The realities of human behavior also dictate that immediate operating decisions take priority over long-term thinking.
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> . . . Means should be found to separate functions of the P.S.A.C.-O.S.T. complex into logical packages, with no one man asked to perform more than is humanly possible. The job of President's Science Adviser is a big one which merits full-time effort. A full-time director should lead O.S.T., and he should have a far better staff. Finally, we need a Planning Office headed by a man who can think and who can marshal the wisdom of this nation in attempting to give guidance for the future.

Some Current Problems of Government Science Policy

What should be the balance between expenditures on pure and on applied science, and who should set it?

Harold Orlans

In the fall of 1963, much concern was evident in the scientific community about the course that several congressional committees would take in their inquiries into federal research and development programs; and the concern of interested parties is always evident at the time of the President's budget message and subsequent appropriations hearings in Congress. Now that the Select Committee on Government Research has completed its work and the House Subcommittee on Science, Research, and Development has finished its round of hearings and reports, I believe it would be generally conceded that the committee members and their staffs did an excellent and constructive job. Both committees—particularly the select committee chaired by Representative Carl Elliott of Alabama—broke new ground. It is not necessary to agree with every one of their recommendations to acknowledge that, under severe time pressure, they asked trenchant questions and gathered and published fresh and insightful information about the nation's gargantuan research-and-development enterprise. However, the fact that this special congressional effort was required to bring to light current and comprehensive statistics on such matters as the geographical distribution of federal R&D funds and the amount received by leading universities and companies suggests that the executive agencies responsible for informing the public about these expenditures had not been doing their job adequately. Let us hope that in the future these agencies maintain the standards of fuller and more timely reporting which have now been set with the assistance of Congress; for we can hardly expect to have either good current policies or adequate consideration of desirable new policies without comprehensive, timely, *and public* information about existing R&D programs.

As the rate of increase of federal R&D expenditures has been declining and as the volume of expenditures in major agencies like the Department of Defense, the National Aeronautics and Space Administration, and the Atomic Energy Commission has leveled off or declined, a major issue of public policy—and of public and private conflict within many agencies and their constituencies—has been posed: how much of the pie should go to basic research? Or, to put the matter another way, how much should go for research at universities, and how much for research and development in industry?

The Doctrine of the Sparrow

The answer of academic scientists is not entirely surprising: more should go to them. With a monotony that bespeaks a unison more than an originality of thought, they and their spokesmen in Washington argue that

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The author is a member of the senior staff of the Brookings Institution, Washington, D.C. This article is the text of a talk given 26 April 1965 at the Tenth Institute on Research Administration of American University, Washington, D.C.

there is no danger of spending too much on basic research; that all "competent" university scientists should be supported to do work of their own choice; that science is an indivisible whole and all fields merit support equally (although some fields merit support more equally than others); that, while the results of any particular basic research project are unpredictable, it is not merely probable but virtually certain that the results of *all* basic research will yield a value greater than their cost. Some of the more ardent advocates of pure science even assert that the results of *any*—or *almost* any—pure research will *certainly* be rewarding, scientifically and socially, conceding only that one cannot predict precisely where or when the reward will be found or who will receive it. This may be termed a contemporary scientific version of the doctrine of the sparrow or the falling leaf—that no harm, no matter how slight, can befall a living thing without serving a higher moral purpose. As purposelessness and futility are thus vanquished in theology, if not in life, so, in the current eschatology of research, error, triviality, and important findings whose importance is unrecognized all equally serve the higher purposes of science. Thus, Alan Waterman, former director of the National Science Foundation, has declared that "The results of such [basic] research, in competent hands, are never without value. Even when no breakthroughs appear, the total effort always brings a possible breakthrough closer"; and he has spoken of "the statistical evidence [which was not, however, further identified] that most of the body of science ultimately achieves practical utility" (*1*). The fascinating justification of heavy federal expenditures on high-energy physics recently advanced by 30 distinguished physicists also dances delicately along the line of statistical likelihood—variously appraised as certain, probable, unlikely, and "not impossible" (*2*)—that these expenditures will yield a significant practical return. I do not doubt that they will yield *some* practical return: this one expects from the work of oafs, let alone that of brilliant men. The critical question—and I wish only to submit it, not to answer it—is: Will it yield a return commensurate with its cost, or greater than the return that can be anticipated from a comparable investment in other fields of science and technology (not to mention other areas of human endeavor)?

An Inconsistency

A striking inconsistency is apparent in the logic of many analyses of federal R&D policies. At times, the relation between the amount of money the federal government spends for basic research and the amount it spends for development is stressed, as when it is said that basic research expenditures are "only" x percent of the total R&D expenditures, whereas development expenditures are nx percent; therefore, it is argued, if economies are needed, the larger rather than the smaller amount should be cut, or carefully "scrutinized" (why not scrutinize both?). However, at other times, it is stressed that basic research should not be compared with development. Thus, it is, of late, increasingly contended that the basic-research expenditures of an agency should not compete with its expenditures on the development of new technology (which should compete instead with expenditures for the procurement and maintenance of existing technology, and other operating needs).

What, then, if anything, *should* basic research expenditures compete with? The answers to this question are frustratingly vague: indeed, no really satisfactory answer has yet been given, although there has been no lack of adventitious suggestions, ranging from expenditures on gambling or tobacco to some arbitrary percentage of the gross national product—all of which are proposed on the condition that they allow adequate scope for expansion. However, one significant suggestion was offered recently by the President's science adviser, Donald Hornig, in a letter to Senator Pastore, chairman of the Joint Committee on Atomic Energy, in which he stated that "the level and character of support for high energy physics must be determined and periodically reassessed in the context of . . . the overall national science program (rather than in relation to the applied research and development programs of the AEC) . . ." (*3*).

To my mind, there is still a good deal of usefulness in comparing expenditures on basic research with those on applied research and development, if only because these sums draw to one type of activity or the other men of comparable training—and I mean by this not only Ph.D.'s and Nobel prizewinners but the more numerous serfs of scientific and technical fiefdoms with mere master's and bachelor's degrees, and their auxiliary corps of glassblowers, machinists, secretaries, accountants, and groundkeepers. Although it was undoubtedly justifiable, immediately after the war, to complain that government expenditures on basic research were but a small percentage—evidently no more, and probably less, than 6 percent—of the $1 billion then spent on R&D, the 11 percent devoted to basic research in 1964 and the more than 14 percent proposed for 1966 out of some $14.6 billion (excluding capital plant and facilities) seem, on the face of it, not utterly, irredeemably, and tragically inadequate. Indeed, if the proportion of government funds going into university research were to be slightly reduced while that going into various forms of more direct aid to higher education were to be correspondingly increased, diverting a number of professors from laboratories to lecture rooms for another hour or two a week, the average quality of both education and research might well be enhanced.

If there is a portion of the R&D spectrum where national expenditures now appear patently inadequate to meet national and international needs, surely it is no longer the realms of pure science but those areas of obsolescent or inefficient civilian technology, at home and abroad, in which the prospect of private profit has been too dim to elicit enough private capital to ensure technical progress, while public expenditures have been blocked by the difficulty of devising a political formula acceptable to the major parties concerned. When the $7-million program of assistance for civilian technology proposed by the Department of Commerce a couple of years ago was rejected by Congress, it was noted in Sweden that their government was spending more—absolutely, not relatively—than the United States government on such programs. Surely, no R&D task merits greater priority today than the search for politically viable ways of utilizing engineers and scientists no longer required for military work to render industries like housing, transportation, textiles, and coal more efficient; to reduce the pollution of air, water, and soil; to improve our systems of education, medical care, and local government; and to raise the standards of living in impoverished areas of this and other nations. It is strange how much money and ingenuity are devoted to searching for indirect, accidental, and even surreptitious benefits of academic, military, and space research and development, and how little to R&D programs of direct and evident social and economic utility. Have we become so muscle-bound politically that, like Primo Carnera, we can display our strength but not use it where it is obviously needed?

A National Budget for Basic Research?

To return to Hornig's very interesting statement that the level of support for high-energy physics "must be determined . . . in the context of . . . *the* overall national science program . . ."—and the definite article which I have italicized is not the least interesting part of this statement, since it alludes to something which simply does not exist. What is advocated here for one field of science must, in principle, be applied to any and every other clearly recognized field. It appears, in short, that the president's science adviser is advocating the preparation of a national or at least a federal budget for all fields of basic scientific research. A number of other signs point in the same direction: the greater separation of government-wide expenditures on development and on research in Special Analysis H of the 1966 federal budget; the energetic and not entirely noncompetitive efforts by committees of the National Academy of Sciences to define and project desirable budgetary levels for various fields of science; and particularly the attempt by an *ad hoc* committee appointed by Academy President Frederick Seitz to grapple with two difficult but inescapable questions about scientific allocations posed by Representative Daddario's Subcommittee on Science, Research, and Development (*4*):

> 1. What level of Federal support is needed to maintain for the United States a position of leadership through basic research in the advancement of science and technology and their economic, cultural, and military applications?
>
> 2. What judgment can be reached on the balance of support now being given by the Federal Government to various fields of scientific endeavor, and on adjustments that should be considered, either within existing levels of overall support or under conditions of increased or decreased overall support?

Although some may feel that the Academy committee has dodged its assignment, rather than confronted it squarely, by answering these questions in the form of 15 separate essays written by individual committee members, it is nonetheless gratifying to see the questions being seriously faced at last, and the resultant document (*5*) is a significant contribution to the thin but growing literature on the aggravating problem of scientific choice.

The new efforts of the National Science Foundation to examine the same problem of scientific allocations should also be noted; these were reported recently by Foundation Director Leland Haworth (*6*):

> The Foundation . . . plans to give additional emphasis to the compilation and analysis of data which bear specifically on the question of relative total levels of support and measures of apparent needs. . . . Thus, we hope eventually to be able to cite fairly precise figures relative to the average amount of total research support available to academic scientists, by field of science, and to augment such data with judgments from competent people in the various fields on the question of reasonable ranges of support levels for each discipline. . . . The problem of making interfield priority judgments should become more manageable if somewhat more complete information on a field-by-field basis can be made available.

The establishment of such a central data bank on federal research grants and contracts is to be commended and should materially assist the rational allocation of scientific expenditures by both public and private agencies—provided that the raw data are not husbanded and used by one camp or another as a weapon in its struggle for a share of limited funds, but are made freely available to all to enlarge our knowledge of national allocations to—and returns from—various fields of science. Too often in the past certain data relevant to public policies have been regarded as proprietary and released only in politically convenient tabulations. Let us, again, hope that the agencies responsible for formulating federal policies for science will adopt the same principle of the fullest possible disclosure of data that is universally accepted with regard to the data of science itself.

No one observing the Washington scene can, however, be so deluded as to believe that key decisions always are or can be made in public and based solely on considerations known to the public. The inner councils of government are always, to some extent, obscure; the passage of time gradually enlarges the public record of private deliberations while reducing both its authenticity and its relevance to future decisions; and available records of the process of decision in major scientific programs are sparse indeed. Except for such information and insight as can be gleaned from congressional hearings, evidence is not generally taken in public; deliberations proceed behind the necessary or convenient cloak of executive or legislative privilege, and the final pronouncement commonly resembles a brief for one side more than a dispassionate examination of available alternatives.

The Composition of the Jury

In this situation where verdicts are reached in private, the composition of the jury assumes a special importance: it provides, in fact, the principal visible assurance that justice is being done. The composition and method of selection of important scientific policy groups therefore merits continuing public scrutiny and discussion. Social scientists have managed to secure representation on an enlarged section of the National Research Council and an occasional appointment to the National Science Board, but none has yet been selected for the President's Science Advisory Committee. Engineers have been so dissatisfied with their status in the National Academy of Sciences that they have formed an academy of their own. The composition of the President's Science Advisory Committee was perhaps adequate to its earlier responsibilities of advising upon the value of proposed weapons systems. However, as the committee's responsibilities have broadened to the formulation of general government policies for science and technology, and as the machinery for implementing its advice has been strengthened, the committee's credentials for performing these larger tasks should be periodically reassessed. The geographic concentration of its members has fortunately been broadened by the latest round of appointments, but the addition of a few more members from industry and a few from selected fields of social science would strengthen the committee's competence to deal with some of the problems which it now faces.

Finally, a few words about what is sometimes regarded as the missing link in the establishment of national policies for science and technology: Congress. Congress has been quicker to see, and to act upon, deficiencies in the executive's formulation and coordination of R&D policies than to remedy its own deficiencies. There is a clear need for improved mechanisms within Congress, comparable to those which have been developed in recent years within the executive, for handling the flow of scientific programs and budgets on a basis that is broadly consistent and campatible with the national interest. The appointment of a new unit in the Legislative Reference Service of the Library of Congress to provide information on scientific and technological programs and policies, the continuing work of the Daddario subcommittee, and the establishment of the new permanent Subcommittee on Research and Technical Programs of the House Committee on Government Operations, under the chairmanship of Representative Henry Reuss of Wisconsin, indicate a recognition of the problem. Is it too sanguine to foresee further Congressional steps to define national rather than sectional goals for science and technology and to enlarge the authority of Congress as a whole in the making of science policies?

Summary

The problems of government science policy I have noted are not exactly new, but each has, I believe, acquired a new degree of urgency from the pressure of events: How much should be spent on basic research and how much on civilian technology? How can reasonable allocations be made among various fields of science? Who is to make these allocations, in the executive and in Congress? The degree to which we can, by objective research and perceptive analysis, accommodate the accidents of history and politics to the changing needs of science, industry, and society will determine the degree to which we can serve not the interests of those groups and individuals (both scientists and politicians) who happen to be in positions of power, but the present needs of the nation.

References and Notes

1. A. Waterman, Director's Statement, in *Nat. Sci. Found. Ann. Rept.* **8**, xii (1958); *Science* **147**, 16 (1965). In contrast, John Jewkes argues that "the overwhelming mass of scientific thought and observation in the Western world was never designed to bring, has not brought, and is highly unlikely ever to bring the slightest improvement in material standards of living" [*Economic Journal* **70**, 14 (Mar. 1960)].
2. See R. Sachs, H. Primakoff, H. A. Bethe, and J. R. Oppenheimer, all in *The Nature of Matter: Purposes of High Energy Physics*, L. C. L. Yuan, Ed. (Brookhaven National Laboratory, Upton, N.Y., Jan. 1965); see also *Science* **147**, 1548 (1965).
3. From letter, dated 27 March 1964, from Donald Hornig to Senator John Pastore, in *High Energy Physics Program* (Joint Committee on Atomic Energy, Feb. 1965), p. 57.
4. *Basic Research and National Goals* (Committee on Science and Astronautics, House of Representatives, Mar. 1965), p. 1.
5. *Basic Research and National Goals*, report of the Committee on Science and Public Policy, National Academy of Sciences (U.S. Government Printing Office, Washington, D.C., April 1965).
6. L. Haworth, "Director's statement," in *Nat. Sci. Found. Ann. Rept.* **14**, xxv (1964).

Within a single generation, science and technology have so permeated our society and economy that there remains scarcely a part of the Federal Government not profoundly influenced and affected by Federal research and development. With this change has come a congressional involvement with science that has increased markedly from year to year. Today almost every committee of both the House and the Senate is concerned with science and technology, albeit in varying degrees. Legislative committees whose interests are *primarily* scientific include the House Committee on Science and Astronautics, the Senate Committee on Aeronautical and Space Sciences, and the Joint Committee on Atomic Energy. A quick look at the jurisdictions of other committees reveals scientific and technological interests of the Joint Committee on Economics; the House Committees on Agriculture, Armed Services, Education and Labor, Foreign Affairs, Government Operations, Interstate and Foreign Commerce, Judiciary, Merchant Marine and Fisheries, and Post Office and Civil Service, and the Senate Committees on Agriculture and Forestry, Armed Services, Commerce, Foreign Relations, Government Operations, Judiciary, and Labor and Public Welfare.[2] These scientific interests generally are a part, not the whole, of the committees' jurisdictions. Furthermore, most of the committees confine themselves to after-the-fact reviews. Except for those committees which participate in advance planning through exercised authorization functions, most others have confined themselves largely to ad hoc investigations of specific aspects of Federal research and development which limit their opportunities to lead in shaping national science policies. At present, the programs of the Atomic Energy Commission; the National Aeronautics and Space Administration; the Department of Defense for procurement of aircraft, missiles, and ships, and for research and development; the Arms Control and Disarmament Agency and foreign aid require annual authorization.

The Appropriations Committees of the House and the Senate have a special sort of role and their influence and impact is of a different kind. They are strategically placed to influence important aspects of policies and programs for science and also in prescribing specific limitations as well.

In the Senate, the continuing interest of the Government Operations Committee in science information is well known, as is also its interest in a Commission on Science and Technology. It was the Subcommittee on National Policy Machinery of that Committee which is credited with the suggestions for reorganizing scientific activities in the Executive Office which resulted in the establishment of the Office of Science and Technology. A few months ago, in August, the Committee on Government Operations announed appointment of a Special Subcommittee on Government Research to conduct studies and hearings into the operations of Federal research and development programs.

In the Senate also, the Select Committee on Small Business held extensive hearings on the role and effect of technology in the nation's economy during 1963. Recently, during May and June 1965, the Employment and Manpower Subcommittee of the Senate Labor and Public Welfare Committee held hearings on the impact on national scientific and technical manpower of Federal research and development policies.

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[2] For further details, see U.S. National Science Foundation. Federal organizations for scientific activities, 1962. Washington, U.S. Govt. Print. Off., 1963, 598 pages. At pp. 557–563.

Recommendations from congressional studies that Congress acquire its own scientific staff led to the establishment of a Science Policy Research Division within the Legislative Reference Service of the Library of Congress.

The fragmentation of Federal science among the Committees of Congress poses a problem of congressional management of its own affairs so that it can give better attention to the whole of Federal scientific activities. Despite this fragmentation, members and committees of Congress are beginning to ask probing questions about the purposes and policies of Federal science. The intention is not so much to take over the policy initiative for scientific research as it is to assure that someone within the executive branch should seize the initiative and do it well and thoroughly.

Some of the questions likely to be pursued in Congress include:

What indications are there of a broad strategy for science in public affairs?

What framework is there for considering the effect of science and technology in regard to the national economy and the development of policy concerning it?

How can issues of Federal research and development be identified before they reach the crisis stage? How can executive accountability for Federal research be improved?

Is sufficient attention being given to setting priorities for choice among different possibilities for Federal basic research?

How can Congress satisfy itself that scientific activities which cut across agency lines are in balance and are effectively coordinated?

What are the facts about concentration of Federal research funds in certain institutions and areas of the country, and what are the implications?

Should the executive branch, through the Office of Science and Technology, prepare an annual report on the substance, organization, costs, goals, problems, and progress of science and technology? This might be a strategy document similar to the Economic Report of the President, and could be complemented by evaluations from the National Science Board and the Foundation on the Nation's resources for science.

Concern over these and other questions has been reflected in recent congressional activities. In the House the principal expressions of this concern have included the studies of this subcommittee, the establishment of the Select Committee on Government Research, the subsequent designation of a Government Operations Subcommittee on Research and Technical Programs, and the introduction of H.R. 15 and H.R. 5609 in the last Congress. The proposal in these bills to create a Commission on Science and Technology is a clear expression of congressional interest in the effectiveness of government programs, organization, and operations for scientific and technological research.

The appointment of a Subcommittee on Research and Development by its Armed Services Committee, of a similar subcommittee of the Government Operations Committee, and the introduction of S. 1136 as a companion bill to H.R. 5609 are corresponding examples of senatorial concern.

This growing congressional activity shows a readiness to come to grips with the problems and issues of government research and development. In fulfilling its legislative role of setting national policies, Congress should exert strong leadership as it formulates fundamental objectives to be set before the departments and agencies. Consonant with this should be greater congressional attention to setting the national policies for development of the manpower and institutions necessary for future national research undertakings.

SCIENCE AND LEGISLATIVE POLICY

By Herbert Roback

A Constitutional Note

The word "science" appears but a single time in the Constitution of the United States, and, significantly enough, in connection with the powers of Congress. Article I, section 8, clause 8, recites: "The Congress shall have power . . . . to promote the progress of science and useful arts . . . ." True, the grant of power was directed toward private incentive in advancing scientific progress; namely, assuring to authors and inventors exclusive rights in their "writings and discoveries" for limited periods of time. It did not imply the expenditure of public funds except, possibly, for the administration of patent and copyright laws. Nevertheless, the association of science and Congress is hallowed by explicit constitutional wording, and this is something more than can be said for the relation of science to the other branches of Government.

Science Incorporated

The constitutional blessing did not escape those American scientists who, one hundred years ago, petitioned the Congress to do something more for science--to incorporate the most eminent among them in a National Academy of Sciences. Joseph Henry, first Secretary of the Smithsonian Institution and its guiding light for the first thirty years of its existence, said in one of his annual reports after he became President of the National Academy:1/

> It is not enough for our Government to offer encouragement to the direct promotion of the useful arts through the more or less fortunate efforts of inventors; it is absolutely necessary, if we would advance or even preserve our reputation for true intelligence, that encouragement and facilities should be afforded for devotion to original research in the various branches of human knowledge.

1/ Frederick W. True (editor), The National Academy of Sciences, 1863-1913, Washington, D. C., 1913, p. 14

Two Reasons for Federal Recognition

The advocates of a National Academy of Sciences were moved, we are told,[2] by two strong impulses:

(1) A prestige factor, to acquire a "badge of distinction" which a national legislature could bestow as the democratic equivalent of the honorific standing accorded to scientists in European countries by special titles, pensions, and other emoluments.

(2) Patriotic service, a deep-seated conviction that this great experiment in democracy on the American continent, attended by a burgeoning population and steady material progress, required that science be enlisted actively in the concerns of Government.

The act of incorporation for the National Academy was done in the midst of civil war; and then and afterward, the participants marveled that the 37th Congress of a Nation so preoccupied with the bloody struggle for survival, would take time to legislate for the advancement of science, culture, and human welfare by granting a Federal corporate charter to a scientific organization.

A Quick Charter Grant

Actually, the legislative business was done with dispatch. The bill of incorporation was introduced by Senator Henry Wilson, a shoemaker by trade and a politician by preference, who rose from offices in the Massachusetts legislature to successive terms in the United States Senate, later to serve as Vice President of the United States with Ulysses S. Grant. The bill went through the Congress without a murmur of protest, without a report or any debate. It was signed by President Lincoln on March 3, 1863. (This is the hundredth anniversary of the National Academy of Sciences.)

Science for War

The less idealistic observers of the day suggested that the legislators were favorably disposed toward a national science organization because the bill contained a provision allegedly designed to appeal to the pragmatic sense of the Congress--an obligation upon the

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2/ Ibid., Chapter I.

National Academy to render scientific service to the Government. With a nation at war, scientific talents were in demand, and the National Academy of Sciences was, in a sense, the first national mobilization of science for war. The Academy carried on this crisis tradition when it offered its services to President Woodrow Wilson in 1916, leading to the formation of its "operating agency," the National Research Council.

The distinguished incorporators of the National Academy, the scientific leaders of their day, did, in fact, concern themselves, upon Government request, with such mundane tasks for the Union cause as preventing mold on Army knapsacks, detecting adulteration in whisky for patients in Army hospitals, preventing rust on the iron bottoms of old Navy prize ships, and ascertaining why boilers on new Navy gunboats blew up. The National Academy founding members also made more exalted scientific investigations, of course, but the fact remains that they had an important role as scientific servants of the Government--and this included service to the Congress as well as to the executive departments. The annals of the Academy show that the Congress did not hesitate to call upon the National Academy for scientific studies which would aid in the resolution of important public issues and in the enactment of wise legislation.

Service beyond Science

These congressional and other Government demands had, for the most part, a practical bent and, the tasks put upon the scientists were not always confined to strictly scientific or technical matters. On occasion, the Academy members, working through their special committees, found themselves formulating public policies on forest lands and other natural resources, recommending organizational changes in the scientific agencies of Government, drafting legislation to carry out their recommendations, and getting immersed in public controversies of a kind which have a familiar ring today.

Some Familiar Problems

Was there unnecessary duplication and wasteful effort in the several sets of rival agencies within the Department of Interior and the Army Engineer Corps which were mapping the United States territories west of the Mississippi? (No less than six Federal units were engaged in these tasks.)

Would the Weather Bureau gain in stature and efficiency by becoming a completely civilian-controlled agency rather than remain in the Signal Service of the Army where it originated?

Did the work of the Geological Survey duplicate that of the Coast and Geodetic Survey, and could functions of the latter agency, then in the Treasury Department, be more economically performed by the Navy's Hydrographic Office?

Would it make sense to consolidate all the scientific agencies of the Federal Government into a Department of Science?

These and other questions came before the National Academy in its studies for the Congress during the first few decades of its existence, serving to remind us that certain problems of Government are perennial and that scientists associated with Government inevitably get drawn into policy issues not altogether within their province. Even when the questions require "scientific" answers in the strict sense of the term, sometimes scientific evidence is lacking, or partial, or tentative, giving rise to conflicting judgments even within the scientific community, and making it easier for other considerations to intrude or prevail.

Scientists' Role in Mundane Things

Thus, if scientists are asked to assess the worth or menace of some simple item of consumer interest, like battery additives, or insecticides, or cigarettes, they can't always expect to be taken as the court of last resort. Usually the Congress is involved in greater or less degree, whether because corrective legislation is proposed, or administrative practices of Federal agencies are under review, or contending producer and consumer interests are seeking a congressional forum. Scientific authority may serve to clarify (or confuse) the issues, depending on the state of scientific knowledge of the subject, the availability of findings from rigorously controlled experiments, or the consistency of evidence from scattered sources. But scientists who would serve the Congress in the resolution of these issues must be prepared to have their contributions praised or criticized, accepted or ignored.

Voice in Great Affairs

And if scientific authority is not always the supreme court in adjudication of mundane technical matters, neither is it--nor should it be--the controlling voice in the larger, more crucial and dramatic affairs of state. Whether it be a nuclear test ban agreement, civil defense, a communications satellite system, atomic power, a lunar program, or any other proposal for serious commitment of national behavior and resources which is dependent upon scientific techniques and disciplines, scientific experts are sought out and consulted, but the policy determinants do not lie exclusively in their domain. Requirements of military strategy may be involved--or sensitivities of friendly foreign countries. Political acceptability at home and psychological value abroad may have to be assessed. Competing demands may lie upon the use of scarce national resources, so that priorities are in order.

These and other considerations are not necessarily within the grasp or the competence of the scientists. Solutions are hammered out or delicately wrought in a variety of patterns by numerous participants in policy making, not the least of which is the Congress.

Witch Doctor to the World's Ills

The point about unjustified extensions of the scientists's role is worth special emphasis, and Albert Wohlstetter of the Rand Corporation has done it rather well in his article, "Scientists, Seers and Strategy," published in the April 1963 issue of Foreign Affairs magazine. In this epoch of history, when technical proficiency through scientific achievement is so crucial to freedom and survival, the scientist stands front and center. He commands respect and admiration and gratitude and attention from the nation which is thebeneficiary of his genius and hard work. The great danger is that the authority and eminence of the scientist will be used and abused to advance or retard all kinds of causes and undertakings in the common belief that be possesses a superior kind of wisdom in a wide range of public affairs.

Most great undertakings, which by their very size, cost, and public importance and necessity, are financed by the public treasury, require cooperative effort. They call upon talents in many fields--of the scientist, the engineer, the soldier, the statesman, the politician, the administrator, the industrialist, the worker. We ought not to create a mystique of science which makes the scientific man the witch doctor to the world's ills.

Who Makes Policy?

Because many hands and brains go to make up a program or project, policy-making is the resultant of many forces. In the governmental scheme of things, policy decisions, gathering coherence, force and direction as they develop, finally come to rest--that is, to be made--in formally designated sources of authority. When the Congress approves--perhaps with modifications--the policy that the executive presents, whose policy is it? When the President signs the policy bill that the Congress has enacted, whether it originates in the Congress or the executive, whose policy is it? The real question in such cases is not whether it is the President's policy or the Congress' policy, but whether it is good policy, representing a consensus of the responsible sources of authority whose word and deed must give it effect.

The role of Congress in policy--and here we refer to science policy and scientific programs--is rather complicated and easily misunderstood. For purposes of this discussion, we might consider briefly in what sense Congress is a policy maker, and this will necessarily include a look at Congress as fund raiser and as agency supervisor.

Has Congress Lost Control?

"Policy" like "science" is an elusive concept. In the very broadest sense the Congress makes all policy because it writes the laws of the land and provides the funds for their administration. Students of Congress, and Congressmen themselves, frequently say that Congress virtually has lost control of policy to the Executive Branch, whereupon proposals are made to recapture the congressional initiative by enlarging committee and office staffs and establishing scientific and other experts as advisory groups to the Congress.

Others would rely upon the special aptitudes of our elected representatives, as political experts, to judge men rather than scientific ideas and to repose full confidence in the policy decisions of those suited by talent and training for scientific judgments. The analogy is made to the growing practice of Congress in recent years, as technology advances and issues become more and more complex, to delegate broad areas of legislative responsibility to independent boards and commissions, reserving to itself a general review function, particularly when the annual budget comes up to the Hill.

Vannevar Bush's Rationale

This was the rationale developed by Dr. Vannevar Bush in advocating, just after World War II, the establishment of a National Science Foundation. The proposal took form in his famous report to President Roosevelt in July 1945, entitled "Science the Endless Frontier." Dr. Bush envisaged a small group of eminent scientists in private life who would give part of their time to the formation of science policy, designating a director of the proposed new foundation to execute their decisions, largely by way of grants to colleges and universities for the conduct of basic research deemed important to the national defense and welfare.

The Congress, after several years of study and debate by several committees, adopted Dr. Bush's basic concept and enacted thenecessary legislation, only to have it vetoed by President Truman. In a strongly worded veto message of August 6, 1947, the President objected to vesting responsibility for the formulation of vital national policies, the expenditure of large public funds, and the administration of important governmental functions, in a group of individuals who would be, as Mr. Truman saw it, "essentially private citizens." The Congress might be willing to accede to such an arrangement, but as far as the President was concerned, it would violate his constitutional mandate to see that the laws were faithfully executed.

A Compromise for Science Foundation

The appropriate structure for the National Science Foundation was debated for five years in Congress, with a half dozen or more committees getting into the picture. Finally, in 1950, a fairly simple but rather unusual compromise was worked out--a compromise between scientific autonomy in the top policy board and Government responsibility for direction of the agency's work. The director as well as the policy board was to be appointed by the President and confirmed by the Senate, the director being answerable to the President and responsive to the board. In its first year, the National Science Foundation received $3½ million. The budget request for fiscal year 1964 is $589 million. One can understand why President Truman wanted a firm measure of executive control.

Atomic Energy Takes Precedence

In the days and months immediately following World War II, the serious concern of scientists and Government leaders in the Executive Branch and the Congress that the wartime values of scientific research must be conserved and continued in peacetime through the appropriate governmental organization--the National Science Foundation--was matched and even exceeded by another kind of concern and another vast area of scientific endeavor--atomic energy. Here the stakes were larger and the demands for solutions more compelling, because atomic energy not only carried the sinister promise of mass destruction but the bright hope of mass benefit through atomic power and other peaceful applications. And so, while it took five years to prepare the legislative ground for the National Science Foundation, it took hardly a year to establish the Atomic Energy Commission.

"Not a Job for Political Hacks"

Interestingly enough, Dr. Bush, whose important contributions as Director of the wartime Office of Scientific Research and Development placed him high in the councils of Government, worked in both areas to mold the proposed Atomic Energy Commission and the proposed National Science Foundation in much the same pattern. For one there would be a top policy group of part-time scientists, for the other a top policy group of part-time scientists and full-time military men. In atomic energy, regulation and control, considering the potential hazards, were of paramount concern, and as two students have recorded Dr. Bush's view, this was a job for scientific experts and military men, "not a job for political hacks or even for well-intentioned laymen."[3]

Civilians and Laymen Prevail

In the final result, while Dr. Bush's influence was great, it was not decisive; the Atomic Energy Commission, as created by law in 1946, would be a full-time job for civilians, primarily laymen and lawyers, with scientists distinctly a minority in top policy formation. The Commission members and the general manager to run the agency operations would be appointed by the President and confirmed by the Senate.

The legislative developments which led to the establishment of the Commission, as in the case of the Foundation, reflected divided counsels among scientists, in laboratories and universities, within the Executive Branch including the military departments, and within the Congress. A big issue, as crystallized in congressional debates, was civilian versus military control of atomic energy. And many nuclear scientists, with guilt feelings about Hiroshima, organized themselves and joined in the legislative fray.

Congressional "Watchdog" Device

One of the notable distinguishing features between the legislative approaches affecting the Foundation and the Commission was the decision of the Congress to provide for itself, in the basic enabling legislation, a continuing mechanism for surveillance of atomic energy affairs. Thus was created the Joint Committee on Atomic Energy with declared statutory rights to be fully informed of the Commission's workings and with other privileges which make it an unusual institution on Capitol Hill.

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[3] Richard G. Hewlett and Oscar E. Anderson, Jr., The New World 1939/1946, Volume I of a History of the United States Atomic Energy Commission, The Penn. State University Press, 1962, p. 409

Contest for Appropriations

Despite the strong mandate and broad jurisdictional scope over administrative and legislative affairs, the Joint Committee was not, of course, the appropriating committee. The Commission's yearly budget, which has varied between $2 billion and $3 billion in recent years, was reviewed by the Appropriations Committees alone (construction and operations separately), and not infrequently, there were conflicts of opinion and judgment between the Joint Committee and the House Appropriations Committee, with the Senate Appropriations Committee more or less allied with the Joint Committee. There were times when the Joint Committee appeared on the floor of the House or Senate as the Commission's defender and advocate against Appropriations Committee budget slashes.[4]

In 1954, when basic amendments were made to the Atomic Energy Act, the Joint Committee took the occasion (after earlier unsuccessful attempts) to write into the law a means for closer and more systematic participation in Commission policy-making beyond the chores of surveillance and the occasional opportunity to wield a measure of influence. This was done by requiring yearly authorizations.

Authorization is Policy Instrument

An authorization is the formal congressional instrument for policymaking. Parliamentary law and practice in the national legislature dictate, with certain refined exceptions which need not be detailed here, that before any appropriations are made, the program or project in question must be authorized by law.

The rationale for this parliamentary procedure is fairly simple and based on long experience. If policy matters and funds were intermingled in the same bill, then inevitably the money bills would be loaded down with "riders" for pet projects of all kinds. Not only would passage of the money bills be delayed, thereby jeopardizing important Government programs and the wherewithal for day-to-day operations, but even if and when the money bills were passed, the President would be put in an untenable position. He would want to veto many objectionable "rider" provisions, but to do so he would have to veto the whole bill. Then the money bill would be killed and the

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4/ Harold P. Green and Alan Rosenthal, Government of the Atom, New York, 1963, pp. 222 ff.

Government operations would grind to a halt.

There are, of course, many riders on appropriation bills even today, although these are subject to points of order on the floor of Congress. Then, too, dollars have a way of making their own policy, regardless of authorizations. Nevertheless, the distinction between an authorization and an appropriation bill is ground into the legislative process.

Single-Shot Authorization

If an authorization is made in one single definitive enactment, then the legislative (policy-making) committee has completed its labors of basic policy formation, until such time as changes in the law are required. The enabling act for the National Science Foundation, for example, represented the formation of congressional policy on basic research. That enabling act in 1950 was a congressional authorization with permanent effect. Thenceforth, the Foundation would determine policy for the Congress by the way in which it disbursed its funds, and the Appropriations Committees would help to shape policy for the Foundation on a yearly basis by their disposition of budget requests.

Yearly Authorizations

For most agencies committed to large scientific research and development programs, the one-time action of authorization given by enabling legislation no longer suffices. The legislative committees insist upon participating more systematically in policy formation by requiring yearly authorizations. This is true for the Atomic Energy Commission, which must justify each year (since 1954) its line item budget to the Joint Committee before going to the Appropriations Committees. It is true for the Department of Defense, which must justify each year (since 1960) its requests for missiles, aircraft, ships, and other large weapon systems, as well as associated research and development programs, to the Armed Services Committees before going to the Appropriations Committees. And it is true for the National Aeronautics and Space Administration, which must justify each year (since 1959) its programs to the Space Committees before going to the Appropriations Committees. In other words, the legislative committees of jurisdiction are not content to leave the annual reviews of multimillion and multi-billion dollar scientific programs to the Appropriations Committees alone. Authorizations provide another set of checks and balances, and a wider spread of congressional participation in policy formation.

Burden on Witnesses

This dual legislative process-authorization and appropriation--with the process being repeated in each house of Congress, makes for a great many hearings and heavy demands upon the time of busy executive and administrators. It may be inconvenient and even exasperating to high-level Government witnesses who must spend hours, days, or even weeks before congressional committees, substantially repeating their testimony from one to the other, sometimes suffering delays when other witnesses take up too much time, or merely sitting by when Senators and Representatives must interrupt the hearing sessions to answer roll calls on the floor.

Joint Hearings not Favored

Still, this is the way of the Congress, and little can be done to expedite the process. While the distinction between appropriation and authorization bills has its own rationale for expediting legislative business, it also multiplies committee participation and generates other kinds of delays. Observers who seek ways to reduce the burden of committee work, expedite legislation, and allow members more time for their other duties, sometimes recommend joint hearings by counterpart committees of both houses, and once in a while such hearings actually are held.

However, joint hearings are not a popular idea in our bicameral Congress. Committees differ in jurisdiction and outlook and schedules and staffing, and each prefers in its own time and way to carry out its legislative business. The Joint Committee on Atomic Energy is an exception, being the only joint committee of the Congress having legislative jurisdiction, and its hearings are automatically joint by the terms of its creation. Similar proposals for joint committees on space or on intelligence activities have not prevailed.

Differing Committee Views

Between the legislative and appropriation committees, or between House and Senate counterpart committees there is not always agreement, as one might expect, and sometimes the differences are sharp and emphatic. The administrator fortunate enough to get his program authorized in one house, may not get it authorized in the other, and therefore he will not get the dollars to carry it forward. Even if he gets his authorization bill through both houses, the dollars still may not be forthcoming. It may happen that the dollars are ready and waiting but the authorization is lacking, so the program has to be deferred for another year.

There are even cases when a program is authorized and funded by the Congress against the judgment of the executive, in which case the dollars may be impounded by the Budget Bureau at the President's direction, visiting the same ill fate on a program as denial of authorization or appropriation by the Congress.

House Money Prerogatives

Raising revenues to pay for all these expensive programs is the constitutional prerogative of the House of Representatives. And since taxes are levied and gathered to be spend for public purposes, the House, from the day the first Congress was organized, has taken the initiative in the spending (appropriation) process. All appropriations bills originate in the House. The Senate challenges this prerogative in theory but accepts it in practice.

Since the power of the purse, wielded in the first instance by the House, is what makes the world go round, the House is more actively in the center of policy formation and does more work than the Senate in reviewing the budget justifications. Its agent, the House Appropriations Committee, is the most powerful committee of the whole Congress.

Senate Appeal Function

Historically, the Senate has acted more or less as an appeal body so far as the appropriations are concerned. Many a harried administrator, bruised or beaten by meat-ax budget cuts in the House, has taken his reclama or appeal to the Appropriations committee of the Senate and gained some relief or rescue. Where the margin of money difference in the recommendations of the House and Senate committees is wide, not infrequently the committees sitting in conference split the difference and at least permit the program to survive, if not to flourish.

Congressional Surveillance Functions

Besides authorization and appropriation, the third means of congressional participation in executive policies and programs is supervision and surveillance. All committees are involved in it in greater or lesser degree, being empowered by their own authorizations to maintain continuous watchfulness over the departments and agencies in their fields of jurisdiction.

Surveillance of the executive department and agencies takes many forms. There may be formal investigations, continued over extended periods, in which administrative deficiencies or improprieties in office are placed upon the record, with full press coverage and other publicity. There may be and usually are the periodic "posture" hearings of the committees preparing their authorization bills; these hearings review important developments during the fiscal year and projected new programs, including important policy changes.

Reprogramming actions require reporting back to the Appropriations Committees. Real property acquisitions and disposals in the defense area require reporting back to the Armed Services Committees. Disposals of Federal surplus property by negotiation require reporting to the Government Operations Committees. And there are various other statutory and informal requirements for reporting major governmental actions to the committees of jurisdiction.

There are many informal conferences and consultations, classified hearings and briefings on sensitive matters, installation visits, inspection trips, and a great deal of staff work to keep abreast of agency developments which may be of present or future legislative interest.

The Committee Staffs

All committees have professional staffs, varying in size and competence. And all committees have call on the research resources of the Library of Congress and the investigative resources of the General Accounting Office, which is designated by law an arm of the Congress. The GAO may carry out its own investigations and report to the Congress, or it may detail staff on request, thus obviating the need in many cases for building up large committee staffs.

A good staff man on the Hill, in dealing with scientific and technical matters, is not necessarily a scientist or engineer, although certain committees in the Congress often find it useful to employ one or two persons with such background and experience. The staff man does not have to match scientific wits; he needs to know how to identify the problems of legislative interest and relevance and concern, to wade quickly through masses of documentary material; to skillfully interview persons and examine witnesses; to keep up with scientific developments and agency programs; to know how to work in a political environment; to enjoy the confidence of his committee Chairman and members; and to write easily and well. The committee report is an important means by which information, sifted, digested or distilled by the staff, is disseminated to the Congress and the country.

The staff man in Congress thus has a key role. Backed up by the investigative and legislative power of the Congress, he has at his call all the resources that the country has to offer in the way of information and advice which the Congress may need to perform its legislative functions.

The Government Operations Committee

As a staff member of the House Government Operations Committee for the better part of ten years, I might say a few words particularly about the legislative and surveillance roles of this committee. We work closely with the General Accounting Office because our authorization directs us to receive and examine GAO reports and to make recommendations to the Congress for possible corrective action. We have across-the-board jurisdiction over all agencies of the Government from the standpoint of determining the economy and efficiency of their operations. We have general jurisdiction over matters of Government reorganization.

"Reverse Legislation"

If the President decides, for example, to reorganize a part of the Executive Branch, he may send a reorganization plan to the Congress. That plan is referred to the Government Operations Committees, which review it and make recommendations to the Congress in case an opposing resolution has been introduced. If Congress votes down the negative resolution, the plan takes effect.

Thus a reorganization plan is a kind of reverse legislation. The Congress has delegated certain limited legislative powers of Government reorganization to the President, on the theory that the President best knows how to organize the Executive Branch. The President proposes and the Congress approves or disapproves (vetoes), in contrast to the ordinary legislative course, whereby the Congress proposes and the President approves or vetoes.

Reorganization Plan for Science Office

The Office of Science and Technology, headed by Dr. Jerome B. Wiesner, was created by a presidential reorganization plan which came to our committee. In fact, it originated as a recommendation of a Senate Government Operations subcommittee (National Policy Machinery). The parent Senate committee long has been interested in the effective organization of science agencies in the Government, and has done considerable work in connection with proposed legislation for a Department of Science and Technology.

This is not a new problem, as I suggested earlier, and there is little or no likelihood that such a department will be created in the foreseeable future. Indeed, the Office of Science and Technology was an alternative response to the department concept, providing instead of an operating agency a staff mechanism in the Executive Office of the President for coordinating scientific policies and programs of the Federal Government.

Established at the apex of the executive hierarchy, enveloped in the Presidential aura of power and prestige, Dr. Wiesner's office is in a good position to review the scientific work of the Federal departments and agencies, to promote measures of coordination, and to keep the President and the Congress informed. Because he is so strategically situated to find out and influence what the scientific agencies are doing and thinking, and to integrate their efforts with Administration policy, Dr. Wiesner becomes a natural object of congressional interest and presumably a ready and reliable source for information.

Dr. Wiesner's Committee Appearances

By way of examples, since the beginning of this calendar year--in the past six months--Dr. Wiesner has appeared before at least a dozen committees and subcommittees. He testified on a bill to stimulate water research and promote a more adequate national program; on a Presidential directive calling for an interdepartmental energy study emphasizing research and development aspects; on policies concerning patents which may result from Federally financed research and development; on progress and prospects in coal technology; on the Administration's educational proposals as they relate to scientific and technical manpower; on the report of the President's Science Advisory Committee, "The Use of Pesticides" (appearance on this before two committees); on technological resources which affect the small business role in the nation's economy; and on questions relating to the National Institutes of Health.

In addition to those appearances, Dr. Wiesner appeared before both House and Senate appropriations committees on the budget for his Office of Science and Technology; before the House Committee on Merchant Marine and Fisheries in executive session on oceanographic matters; and before the House Committee on Science and Astronautics in executive session on space matters. He was also invited to discuss manpower questions before the House Committee on Education and Labor but was unable to attend and had to send a substitute.

Does Congress Need Science Advisory Groups?

Considering the many and varied sources of technical and scientific information and advice available to the committees of Congress through Dr. Wiesner's office, through the great departments and agencies engaged in such programs, and through testimony from scientific panels and personalities in universities and other non-profit organizations as well as industry, the question arises whether the Congress will gain any advantages to the legislative process by setting up its own scientific advisory committees.

The National Association of Manufacturers, in a statement submitted to our Military Operations Subcommittee, which is printed in our 1962 hearings on Systems Development and Management, strongly urged that the Congress "establish a special group or groups of scientific and technical advisers, which would be responsible only to Congress." In the NAM's view, industrial research experts, with practical as well as technical experience, would make good candidates for this advisory service.

In his appearance before our Military Operations Subcommittee last year, Dr. Wiesner also expressed the thought that the Congress ought to take steps similar to those of the Executive Branch by better organizing its committee structure related to science programs and by acquiring staff resources to give the necessary scientific advice to the Congress.

These suggestions are beginning to show up in legislative bills. For example H.R. 6866, introduced into the 88th Congress, proposes that there be established in each House of Congress "a staff competent in science and technology." Each science advisory staff would consist of a director and two associates and be available to committees and Members of the House to give scientific advice and assistance in connection with legislation.

Complex Division of Work

A realistic appraisal of the committee structure of Congress discloses the difficulties which would confront any proposal to establish scientific advisory groups either centrally or as adjuncts to particular committee staffs. There are 21 committees and 125 subcommittees in the House of Representatives. There are 18 committees and 100 subcommittees in the Senate. There are 7 Joint Committees with their assorted subcommittees. While defense, atomic energy, space, and commerce committees (in addition to the Appropriations Committees) predominate in the science field, many other committees have jurisdiction and interest in one phase or another of scientific affairs and for one purpose or another, depending on their legislative role.

The jurisdictional areas cannot be neatly delineated. Assignment of legislative bills by direction of the Speaker of the House and the President of the Senate, or of committee tasks by direction of their respective chairmen, do not always follow the written rules. And even if they did, the rules cannot cover the variety of changing situations reflected in legislative processes.

A bill to regulate agricultural surpluses, for example, is referred to the Committee on Agriculture; a bill to redistribute surplus wheat or processed foods for civil defense purposes is referred to the Armed Services Committee which has legislative jurisdiction over civil defense. The primary studies and investigations in civil defense have been conducted in the House by our Government Operations Committee which does not have legislative jurisdiction but has correlative jurisdiction over organizational and operational aspects, and which believes that other committees have neglected civil defense. A Senate bill to establish a Committion on Science and Technology is referred to the Government Operations Committee, because it has organizational jurisdiction, but in the House the same bill is referred to the House Committee on Science and Astronautics because the bill deals with science policy as well as with agency organization.

Dilemmas in Advisory Role

With this complex committee structure and distribution of legislative work in the Congress, a small central group of scientific advisers could not hope to respond to the numerous, frequent, and recurring or continuous legislative demands for information and advice on scientific affairs. And, on the other hand, if the scientific experts were attached to separate committees and subcommittees, it would not be practical except in very limited and informal ways for the staff expert on one committee to assist another committee.

The consequences would be either that the scientific experts would have to build up a big bureaucracy of their own in the legislative branch, which the Congress would not sanction, or they would be bypassed in the hurry and scuffle of legislative work.

If the scientific advisers were full time employees, they would be expected to do many chores beyond their special talents. If they were part time consultants, then they would be too remote from the legislative process to respond to its exigent demands and hence no better placed than witnesses before the committees.

Multiple Sources of Advice

There are in fact varying kinds of scientific advisory services available to the Congress. Apart from the testimony of expert witnesses individually or in panels, several committees have contracted with RAND Corporation and other groups for technical studies. The House Committee on Science and Astronautics actually has a standing advisory panel, established in 1960, of 16 members drawn from major scientific areas. The panel meets with the committee once a year expressing its views and conveying matters of interest and concern in the scientific community. Reports of the panels proceedings are presented by the Committee to the House of Representatives.

Finally, as I said, particular committee staffs will include a few persons with good technical backgrounds when required by their legislative work.

Scientists in a Political Setting

Eminent scientists are always available to the Congress for consultation. They would not, however, be comfortable if they were required to sit continuously or frequently in a political environment, any more than they would be comfortable in a military environment. The one is too loose and casual, the other too tight and regimented. Scientific endeavor has its own disciplines, but these do not seem to flourish in either a political or military setting. The scientific-military relationship is a story in itself. In Congress, scientific talent continually on tap would go to waste, or the natural scientists soon would become "political" scientists.

The Congressmen, I have suggested more than once in these remarks, are eminently practical men. They are practical because politics, as Bismarck is credited with saying, is the art of the possible. In politics the vehicle of possibility, of achievement, is compromise. In science there is no compromise with the laws of nature, and I would suppose that scientists abhor compromise as nature abhors a vacuum. The problems of informing the Congress are not insoluble, in any case. If things get tough, we can always fall back on Dr. Bush's dictum that politicians are especially good judges of people. This being the case, it follows that Congressmen understand scientists better than scientists understand Congressmen.

Congressmen not only know people, they know organizations. They know Government. They discovered Parkinson's law long before Parkinson did. They sharply criticize waste and failure, but they generously praise good work and they admire excellence. Their tolerance is broad, their patience long. They take pride in their Government's achievements. Though the caustic comment, the political sniping, and the occasional absurd action may be played up in the press, the Congress is a dedicated body with a sense of history, of great responsibility and with enduring faith in the United States of America.

SCIENCE AND CONGRESS

by Kenneth Kofmehl
Purdue University

Prepared for delivery at the 1964 Annual Meeting of The
Midwest Conference of Political Scientists, Madison, Wis.
University of Wisconsin April 30-May 2, 1964

Now is the winter of our discontent
Made glorious summer by this sun of York. King Richard III
Act I, Sc. 1, Line 1

To paraphrase the Bard, 1963 was the winter of congressional discontent with science. In January there were intimations of impending cuts in expenditures for research and development. Congressional intent to scrutinize specific projects more closely was indicated by the extension of authorization requirements to the research and development activities of the Atomic Energy Commission, the Department of Defense, and the National Aeronautics and Space Administration. As the session wore on, criticism of these agencies and others administering scientific programs, like the National Institutes of Health and the National Science Foundation, mounted in crescendo. A campaign to improve the ways in which Congress gets scientific advice was launched. And the demand for a congressional probe into the organization, conduct, and total outlay for federal scientific activities became more and more insistent.

Rather surprisingly, this widespread manifestation of displeasure burst out after more than two decades of generous treatment by Congress, which had made the federal government the preeminent patron of science and technology in this country. Verifying Don Price's thesis about the impact of consensuses among scientists on the content and mode of administration of public policy,[1] Congress had established the Atomic Energy Commission, National Science Foundation, National Aeronautics and Space Administration, and Office of Science and Technology for the President largely in accordance with their wishes. These agencies embodied the dominant views of the scientific community on organization, procedures, and policies--such as the desirability of civilian control of atomic energy, peaceful uses of outer space, and a commitment to federal support for basic research and advanced scientific education. Moreover, companion congressional bodies like the Joint Committee on Atomic Energy and the science and space committees pressed for an expansion of some of their programs more vigorously than the Administration. From 1957 on, in response to the indulgent initiatives of the chairmen of the cognizant appropriations subcommittees, Representative John E. Fogarty (D.-R.I.) and Senator Lister Hill (D.-Ala.), Congress had regularly appropriated more than the budget had requested for the National Institutes of Health--sometimes even more than the NIH was able to spend prudently, with a consequent return to the Treasury of unused funds.

What was responsible for this sharp reaction of Congress toward science? As might be expected, a multiplicity of factors interacted. Paramount among them was the skyrocketing growth in federal expenditures for science. The $2.9 billion increase in expenditures for research and development from fiscal year 1963 to fiscal year 1964 was the largest one-year rise in the history of federal spending for science. And this was but the latest in a succession of sharp increases. The amount spent on research and development had grown from $3.15 billion and 4.7 percent of the total budget in fiscal 1954 to $14.88 billion and 15.1 percent of all federal expenditures in fiscal 1964. Going back to the first year for which fairly reliable data are available, fiscal 1940, affords an even more dramatic contrast. In that year, federal funds devoted to R & D were only $74 million and constituted but .8 percent of the total budget.

Even more significant than the magnitude was the exponential rate of this growth. Between fiscal 1940 and fiscal 1964, the increase in federal R & D expenditures averaged 19.8 percent per year very consistently. Obviously, this trend could not continue much longer. For were this rate of growth to persist unabated, the entire federal budget would be devoted to R & D by around the year 1980. And the projected federal R & D expenditures for fiscal 1965 indicated that the rate of growth might already be leveling off. The $15.29 billion estimate for fiscal 1965 was $2.5 billion under what a continuation of the 19.8 percent per year trend would have provided. In any event, knowledgeable persons in the executive branch, Congress, and scientific community became aware that a downward adjustment in the growth rate of federal R & D spending was imminent. And this generated much concern about the need for developing a better means of assigning priorities to the various scientific enterprises supported by federal funds.[2]

A closely related consideration was the economy drive by fiscal conservatives of both parties. The House Republicans formed a task force, which included eleven Republicans from the House Appropriations Committee and was aided by former Budget Director, Maurice Stans, to study the budget and recommend reductions. On March 4, 1963, Representative Frank T. Bow (R.-Ohio), chairman of this task force, announced that $4 to $6 billion should be cut from the proposed expenditures. Representative Clarence Cannon (D.-Mo.), chairman of the House Appropriations Committee, avowed a goal of slicing some $5.4 billion from the budget, which he said was "loaded with waste." And the economy bloc freely admitted that a motive behind the unprecedented delay in enacting appropriations measures was to hold down federal spending.[3] The R & D component of the budget attracted their special attention not only because of recent rapid growth but also because of being far more vulnerable than fixed or well-entrenched items, such as interest on the public debt, veterans' benefits, and agricultural subsidies.

Geographic distribution of funds projected federal R & D programs into congressional consciousness from another direction. About two thirds of federal R & D expenditures are made through contracts with private industry; over ten percent through grants and contracts with universities and other nonprofit institutions; and the rest by government personnel in federal facilities. The competitive struggle among regions for larger shares of these funds has enriched our political vocabulary with the term "pork barrel science." Some of the most bitter battles have been waged over the location of university research centers and federal facilities. For these have a sort of "multiplier effect." Besides contributing directly to the economy of their locale, they attract additional science-based industry, which in turn can obtain more federal R & D contracts in a cumulative upward spiral of prosperity. A current example which should be familiar to this Midwestern audience, if not too painful to contemplate, is the MURA high energy accelerator, which would have cost about $170 million to build and would have had operating costs of about $30 million a year. Perhaps more familiar on the national scene has been the controversy over the site of the $50 million NASA Electronics Research Center--a competition which Purdue entered belatedly and unsuccessfully. An equally famous illustration is afforded by the three-way tug of war between North Carolina, West Virginia, and Maryland for the $33 million PHS Environmental Health Center, which has delayed construction of that installation for more than three years.

The impact of federal R & D spending on universities and colleges spawned an analogous cluster of problems. The flow of federal funds threatened not only to enhance the sciences at the expense of the humanities and social sciences but also to favor certain fields like high-energy physics and molecular biology among the natural sciences. Diversity in practices among federal agencies in awarding research grants and contracts meant that the recipient institutions often might not receive full reimbursement for the indirect costs involved. There was fear that dependence of some universities on the federal government for a large share of their operating costs would impair their academic integrity and independence. Preoccupation of top faculty members with obtaining and administering research projects caused undergraduate training in the large universities to suffer. Without the increasingly expensive equipment required and the higher faculty salaries made possible by federal support, small colleges were in danger of being priced out of the market of producing science graduates. The practice of awarding federal grants and contracts on the basis of existing capabilities resulted in a concentration of federal monies in ten or so leading universities, further aggravating disparities in talent and resources. Some critics contended that the primary factor responsible for this pattern of awards was the system of advisory panels used by the federal agencies in making research grants and contracts. Comprised of faculty members from the big, prestige universities, these panels tended to favor the applications of their colleagues. Summing up this charge very neatly, John Walsh writes:

> Perhaps the chief advantage of the big, rich universities in federal research is that they have Washington representatives of the most effective kind in the faculty members who sit on science agency policy committees and project selection panels. They know each other and they know the science agency bureaucrats, and there is no question that a kind of freemasonry prevails among scientists in the major research centers. Inside observers say that, while panelists strain for objectivity in judging research projects, applications from prestige institutions enjoy a subliminal advantage.[4]

This issue of favoritism in making research awards was but a part of the much larger question of how the federal government could best bring to bear the opinion and knowledge of the scientific community in the formulation of public policy. Although rather badly overdrawn and incorporating some dubious premises, the picture Meg Greenfield painted in "Science Goes to Washington" conveys impressionistically the bases for concern on this score in the executive branch: the confusing maze of advisory bodies; the overlapping memberships among them, the universities, private industry, and professional associations; the difficulty in determining which hat a scientist who occupies multiple positions is wearing; the intramural feuding among scientists; the potential abuses which the secrecy surrounding these bodies may cloak; and the consequent impossibility of assigning responsibility for scientific counsel in the government.[5] Disgruntled scientists and industrialists fanned these anxieties by publicly complaining that dissenting opinions did not have an adequate opportunity to be heard in the process by which the executive branch obtained scientific advice on which to base major decisions.

Nevertheless, whatever the shortcomings in the system, through the panels of the Presidential Science Advisory Committee, the Federal Council on Science and Technology, and the National Academy of Sciences-National Research Council, the Administration had recourse to advice from hundreds of the top scientists inside and outside the government. There was growing concern that Congress had no comparable institutional means of tapping the expert counsel of the scientific community. Congressional uneasiness in this regard was aggravated by the changing composition of the federal civil service. Since 1950 both the number of professionals and the proportion of scientists and engineers had grown rapidly. By 1963, out of the 231,000 or so professional people in the employ of the federal government, about 150,000 were scientists, engineers, or doctors.[6] With few doctors and no scientists among its members, Congress might well wonder how it could equip itself to oversee this aggregation of expertise.

In fact, this whole preoccupation with science and public policy was a local manifestation of a world-wide phenomenon. In Great Britain, in March, 1962, the Prime Minister appointed a Committee of Enquiry into the Organization of Civil Science, which reported to Parliament in October, 1963.[7] The Minister of Science (then Lord Hailsham, now just plain Quintin Hogg, M.P.) published a book Science and Politics, which was circulated in this country in the summer of 1963. And needless to observe, British author C. P. Snow's two booklets, The Two Cultures and the Scientific Revolution and Science and Government have been widely cited in both high governmental circles and the scientific community in the United States. On October 3 and 4, 1963, the ministers responsible for science in the twenty member governments of the Organization for Economic Cooperation and Development met in Paris to discuss "Science and the Policies of Governments." The problems aired had a familiar ring: the need to establish priorities for allocation of increasingly scarce science resources, how best to structure scientific advice into the governmental process, the necessity for governments to make greater efforts to coordinate their national R & D programs, and so on.[8]

In Great Britain, governmental policies toward science is to be one of the major issues of the forthcoming general election. The Labor Party has been trying to make political capital out of the so-called "brain drain," the migration of scientists to the United States (instead of from the Midwest to California or the East). There is even a British equivalent of the MURA controversy with a lively debate on how government support should be divided between national linear accelerators and the international facilities at CERN in Switzerland. Likewise, Soviet scientists and officials are engaging in dialogues over the relations of science and government.[9]

A distinctively American contribution, however, was made by various congressional committees. Over the immediately preceding years, besides the hearings and studies by the committees on armed services, science and space, appropriations, and atomic energy on scientific programs of agencies within their jurisdictions, several subcommittees of the Senate and House Committees on Government Operations had been energetically studying R & D activities, interagency coordination of scientific information and research, and various aspects of governmental organization for science. In the wake of Sputnik, the Subcommittee on Reorganization and International Organizations of the Senate Government Operations Committee recommended the creation of a Department of Science and Technology. Reflecting a consensus within the scientific community, the Administration wisely rejected this proposal in favor of the present arrangement for a scientific advisory staff at the presidential level. Interestingly, in establishing the Office of Science and Technology, the Administration was following a course recommended by the Subcommittee on National Policy Machinery of the Senate Government Operations

Committee, which the Administration adopted in part as a preclusive measure. Undeterred, the Senate Government Operations Committee Reorganization Subcommittee simply modified its tactics to urge the creation of a Commission on Science and Technology to study the problem. On March 8, 1963, the Senate Government Operations Committee persuaded the Senate to approve a bill (S. 816) to set up such a Commission on Science and Technology, which would be required to report by January 1, 1965, recommendations for:

> A Cabinet-level Department of Science and Technology or transfer of scientific functions to existing or new federal agencies (e.g., consolidation of the Atomic Energy Commission, National Science Foundation and Bureau of Standards).
>
> Improved procedures for conducting or financing scientific programs and supporting basic research.
>
> Elimination of duplication among federal agencies engaged in scientific and technological research and in information and distribution services.[10]

A similar bill passed the Senate in 1962 but was not acted upon by the House. Although the prospects for enacting this measure were not great, the supporting arguments and antecedent bills over the preceding six years had given currency to the idea of extensive waste and duplication in federal R & D activities, accentuated awareness of their rapidly growing cost, and underscored the need for a comprehensive study of all the science and technological programs of the federal government.

Although working without much fanfare, the committee which did the most to alter the climate of relations between science and Congress was the Intergovernmental Relations Subcommittee of the House Government Operations Committee, headed by Representative L. H. Fountain (D.-N.C.). In 1959 the Intergovernmental Relations Subcommittee staff initiated a study of the administration of research grants by the National Institutes of Health. In April, 1961, the subcommittee made a report of its findings, which the full committee adopted and issued as House Report No. 321. Although critical of the organization and procedures of the NIH for administering grant programs, the report was constructive in tone and made reasonable recommendations for correcting extant deficiencies. Moreover, other recommendations of the subcommittee revealed sympathetic understanding of the problem of reimbursement for indirect costs of research and of the need for developmental grants to build research capability in a larger number of universities and professional schools.[11]

In correspondence during April and June, 1961, Dr. James A. Shannon, Director of NIH, characterized the report as "excellent" and Dr. Luther L. Terry, the Surgeon General, wrote: "Again, may I compliment you upon a searching and instructive inquiry into the growing and complex set of activities administered by the National Institutes of Health."[12]

On August 1, 1961, at hearings of the Intergovernmental Relations Subcommittee on the report, Surgeon General Terry testified:

> Although the Public Health Service activities are constantly under review, there is a tendency for long-established systems and procedures to appear adequate to those familiar with them even when they may no longer meet all of the new requirements imposed upon them by the growth or the changed character of the programs they serve. A critical review by an objective outside group is therefore of great assistance in calling attention to slowly growing but as yet unobserved administrative deficiencies.
>
> It is in this light in which I view and warmly welcome the report's comments on the administration of the NIH grant and award programs. The intelligent examination of recent practices and the thoughtful recommendations for their improvement are very helpful in focusing attention on problem areas and suggesting the need for revised procedures.
>
> I want to assure the committee that each criticism is being most carefully examined and each recommendation most seriously considered both in my office, by the Director of the NIH, and by those immediately responsible for the grant administration at NIH.[13]

On January 22, 1962, in response to a request from the Intergovernmental Relations Subcommittee for a detailed progress report on action taken by the NIH with respect to each of the committee's recommendations in House Report No. 321, Dr. David Price, Acting Director of NIH, wrote:

> We are in accord with the recommendations of your committee and definitely intend eventually to make all desirable changes needed to effect the sounder administration which your committee recommended.[14]

Despite these endorsements of the subcommittee's recommendations, the NIH did virtually nothing to comply with them. Although the ostensible reason for this inaction was the difficulty of recruiting the type of administrative personnel required, a high NIH official subsequently conceded that the NIH had decided to do nothing, saying:

> Fountain is right that nothing was done after the first report. At that time, we had no comprehension of the seriousness of the matter. We had differences among ourselves as to what should be done, and as a result, we did nothing. Some people felt that no changes were needed, and there was a feeling that time would pass and the whole thing would be forgotten.[15]

Meanwhile, in January, 1962, with the assistance of personnel from the GAO, the Intergovernmental Relations Subcommittee staff made an audit of the NIH research grants to Public Service Research, Inc., a commercial firm operating for profit, in order to provide detailed information on the adequacy of NIH policies and procedures for insuring the appropriate expenditures of public funds. This audit covered the period of July 3, 1959-December 31, 1961, during which the company received $378,596 or 85 percent of its total cash funds, from NIH grants, and revealed a number of serious abuses. Conceding that the amount of funds represented only a small percentage of total NIH grants, the staff report stated that NIH policies and management procedures provide no assurance that practices similar to those followed by the Public Service Research, Inc., were not widespread; for the NIH had admitted in hearings that adequate administrative machinery did not exist either in NIH or in the grantee institutions to ensure effective management of grant funds.[16]

On March 28-30, 1962, the Intergovernmental Relations Subcommittee held another hearing "to obtain further information on the progress of the NIH in implementing the committee's recommendations." Then the subcommittee prepared a strongly critical report, which the full committee adopted and issued as House Report No. 1958 on June 30, 1962. Noting that the NIH had acted on some of the committee's recommendations, the report charged that the NIH had done "relatively little to improve the overall management of its grant programs since the committee's report of April 1961." Attributing the weaknesses in the grant programs "in large measure to the failure of NIH officials to understand the nature of their responsibility for the management of public funds," the report went on to say:

> The committee agrees that the selection of good investigators and good projects is vital to productive scientific research, but the effective management of grants is also a fundamental responsibility of a Government agency charged with administering grant programs.
>
> The committee takes strong exception to the view expressed by NIH that all administrative actions subsequent to the selection of grant projects are "essentially trivial" in relation to the basic selection process. The selection process and grant management are essential and complementary parts of NIH research support. Excellence is required of both.[17]

Despite the castigation of the top NIH officials and the angry tone of much of the language, the report stressed:

> The committee wishes to emphasize that it is fully committed to the principle of allowing scientific investigators the greatest possible freedom of action in carrying out their research. The history of science clearly demonstrates that scientific achievement and progress have generally occurred under conditions which allow maximum freedom of inquiry for the investigator.
>
> However, freedom for the scientist should not be confused with license or fiscal irresponsibility . . . .What we must achieve is a harmonizing of freedom for the investigator with responsibility to the public in the expenditure of Government funds. NIH has the obligation to develop adequate policies and procedures for assuring that grant funds are prudently spent within this context.[18]

After observing that the average quality of NIH grant projects according to the NIH's own statistics had been steadily declining in recent years, the report concluded:

> It appears that the Congress has been overzealous in appropriating money for health research. The conclusion is inescapable, from a study of NIH's loose administrative practices, that the pressure for spending increasingly large appropriations has kept NIH from giving adequate attention to basic management problems. The committee expects NIH to give high priority at this time to the task of correcting its management deficiencies and strengthening its capacity for the effective and efficient operation of these vital health programs.[19]

In response to this report, NIH adopted new policy regulations embodying many of the committee's recommendations in October, 1962, and issued the Public Health Service Grants Manual containing them on January 1963. Among the requirements imposed by the new regulations were: scientists who make significant changes in research projects must report this to NIH; any purchase of $1,000 or more with grant money must be approved by NIH; grantees must keep records and report to their institutions the amount of time put in on the federally financed projects and the institutions must refund NIH money if actual time spent falls short of estimates; and these records are subject to NIH audit.[20]

Although many knowledgeable observers agreed that such PHS regulations were long overdue, the reaction of the scientific community--particularly the medical researchers--was swift and pronounced. Claiming that the regulations burdened researchers with excessive paper work and would cripple scientific inquiry by the restrictions imposed, these critics focused their fire initially on the PHS for having adopted the regulations. As the spring progressed, increasingly they assailed Representative Fountain for having pressured the NIH into precipitately adopting these restrictive administrative practices. The tenor of these attacks is conveyed by the following excerpts from the resolution passed by the American Society of Biological Chemists at its April meeting requesting the National Academy of Sciences to undertake a study of the government's research grant policies:

> The necessity for clearer definition of the relationships involved has been brought into focus by the criticisms recently directed by the Intergovernmental Relations Subcommittee of the House Committee on Government Operations against the management of the research grants program of the United States Public Health Service. While regretting the manner of criticism of the House Committee and their failure to provide constructive leadership, we suggest that the time is indeed opportune and the moment critical for appraisal of the relationships which properly should obtain among the federal government, universities and scientific investigators if the national interest is to be served.[21]

Besides these direct assaults, a counterattack was launched through sympathetic House committees. In April 1963, the House Interstate and Foreign Commerce Subcommittee on Public Health and Safety, which was headed by Representative Kenneth Roberts (D.-Ala.) began hearings on a bill (H.R. 2410) to give the Surgeon General broad powers to reorganize the PHS. Both Roberts and Representative Oren Harris (D.-Ark.), chairman of the full committee, employed them as a means of making a study of the NIH along with the rest of the PHS. From his sympathetic questioning of NIH Director James Shannon, Roberts appeared to be seeking information with which he and Harris could combat NIH critics. The same month in the report accompanying the appropriations bill (H.R. 5888--House Report No. 246) prepared by the Fogarty Subcommittee, the committee expressed concern at reports that the efforts of the NIH to tighten fiscal control over the administration of grant programs "seriously threaten the freedom of scientists, and that they constitute evidence of Federal control over science." Then the report went on to say:

> The Committee is sensitive to the fact that overzealous response to criticism might result in unneeded restrictions. However, the Committee is convinced that what has taken place is a needed and proper clarification of the necessary conditions which accompany the use of large sums of public monies. . . . At the same time, the Committee directs the Public Health Service to exercise a high degree of vigilance that its actions not diminish the basic independence and integrity of our institutions of higher learning, and the essential conditions of scientific freedom.[22]

The response of many scientists--particularly the more vociferous--to congressional and agency attempts to introduce some measure of fiscal accountability for the use of research grants was exaggerated to say the least. Implicit in many of the utterances forthcoming from the scientific community was a philosophy that somehow scientists were morally superior to the rest of mankind and that the federal government should supply them money without questioning the uses to which that was put as long as it went for science. Needless to observe, the expression of such sentiments heightened congressional suspicions that there was widespread carelessness in the handling of funds Congress was providing for the support of science. Disclosures by NSF auditors that the American Institute of Biological Sciences had diverted federal research monies to the production of science motion pictures (with the intent of making restitution when the funds were recouped from the sale of the films), the extensive publicity attending difficulties with the MOHOLE Project, and other evidences of mismanagement of federally financed research programs added fuel to the flames.

Yet another ingredient in the quickly heating stew were the acrimonious public disputes among scientists over fallout shelters, environmental contamination, the test ban treaty, and other political issues with a large scientific content--or reciprocally, scientific issues with strong political implications. Most prominent among these was the debate over goals of the U.S. space program. No occasion was too sacred for scientists to profane with their opinionated views on this score, as Linus Pauling's disruption of the ceremonies celebrating the centennial of the National Academy of Sciences demonstrated. A variety of factors contributed to the intensity of their wrangling. Some scientists were genuinely concerned that a disproportionate amount of scarce resources--particularly scientific manpower which was rapidly approaching a ceiling--would be diverted to the space program while more worthy projects languished. Others, reflecting the biases of their disciplines on such issues as the kinds of data that should be collected, questioned the desirability--much less the feasibility--of the manned lunar landing. Reinforcing these scientific doubts were partisan considerations. Early in 1963, Republicans in both the House and Senate decided to exploit the controversy over the U.S. space program for partisan gain. And the Air Force, disgruntled with its role in space, was eager to supply anyone and everyone with documentation for the criticism that not enough emphasis was being placed on military uses of "inner" space for our national security.

Finally, special mention should be made of the influential role played by Science magazine in general and by its editor, Phillip H. Abelson, in particular. With a circulation of more than 90,000, this house organ of the AAAS reaches most influentials in the scientific establishment and in Washington officialdom. The masthead of Science proclaims the goal of "serving its readers as a forum for the presentation and discussion of important issues related to the advancement of science, including the presentation of minority or conflicting points of view, rather than by publishing only material on which a consensus has been reached." In the area of science and government, Science succeeded admirably in achieving that goal in 1963. The recently expanded and very able staff of the "News and Comment" section provided a comprehensive weekly coverage of significant developments in the "interface of science and politics" on the national and international scene. Free from dictation of an editorial party line, they wrote witty, lucid, perceptive, generally objective but often provocative articles. Supplementing their presentation, as a self-appointed scientific Cassandra, Editor Abelson, penned a series of trenchant editorials plucking at the raveled sleeve of relations between Congress and science. And the feedback to his strictures in the enlarged letters-to-the-editor section stimulated further ntroversy.

On June 6, 1963, Representative Abner W. Sibal (R.-Conn.) introduced a bill to establish a Congressional Science Advisory Staff (H.R. 6866), purportedly at the instance of Dr. John Heller, executive director, New England Institute for Medical Research, and science advisor to Richard M. Nixon during the 1960 presidential campaign. Following the pattern of the Congressional Office of the Legislative Counsel, the bill would establish separate Congressional Science Advisory Staffs for the House and Senate. Each would consist of a director and two associates, none of whom is to be more than 55 years old. Every staff member is to hold a Ph.D. degree or its equivalent, with one from the field of biology, one from chemistry, and one from physics on each staff. Every staff member is to be appointed solely on the basis of fitness and without reference to political affiliation for a term of three years (but shall not be eligible for more than two terms), with compensation of $21,500 a year for each director and $20,000 a year for each associate.

The directors are to be appointed by the President pro tem. of the Senate and the Speaker of the House, respectively. The associates are to be appointed from a list provided by each director; in the case of the Senate, one by the President pro tem. and one by the minority leader; and in the case of the House, one by the Speaker and one by the minority leader. The bill provides for clerical staff and, further, that other individuals may be appointed on a temporary basis by the director of each staff to render such scientific assistance as the director may determine to be necessary. These individuals are to be compensated at a rate of up to $100 a day, plus certain expenses.

Each science advisory staff is to be available to the committees and members of the House of Congress within which it is established and to conference committees of the two Houses to give scientific advice and assistance in the analysis, appraisal, and evaluation of legislation or proposed legislation.

On August 13, 1963, Senator E. L. Bartlett (D.-Alaska) introduced an analogous bill to establish a Congressional Office of Science and Technology (S. 2038), to which he refers by the snappy acronym COST. The following day, Representative William Widnall (R.-N.J.) introduced an identical measure in the House (H.R. 8066).

Though generally similar, the Bartlett-Widnall bill improves on the Sibal proposal in several respects. Only the directors of the Senate and House branches of COST are to be appointed by the President pro tem of the Senate and the Speaker of the House, respectively. Again, they are to be selected solely on the ground of fitness and without regard to political affiliation, but no other qualifications are specified. Each director shall employ and fix the salaries of the assistant director and other employees in his office. The bill does, however, list the following duties of the office in each House:

> (1) upon request, to advise and assist any Member or committee of that House with respect to matters relating to science and technology;
>
> (2) to make studies concerning matters relating to science and technology as may be directed by that House or any committee thereof;
>
> (3) to maintain a register of scientific and technological consultants who have indicated a willingness to advise and assist committees and Members of that House; and
>
> (4) to transmit to committees of that House reports concerning significant scientific or technological developments which pertain to matters subject to the jurisdiction of such committees.

The bill provides that each branch of COST shall assist the joint committees upon request at any time. And it provides that should questions of priority be raised concerning requests made to either office, those shall be determined by the Rules and Administration Committee of the Senate and the House Administration Committee in the House.

Though differing in detail, these two bills (Bartlett-Widnall and Sibal) are sufficiently similar that they can be analyzed jointly. Hereafter they will be referred to interchangeably as the COST measure. While well-intentioned, this proposal is defective in several vital respects. Firstly, it is based on a faulty assumption about the nature of policy issues involving scientific matters. These are not scientific questions which can best be answered by a scientist. Almost every policy question involves many other considerations of a political, economic, social, psychological, or military sort. And even the scientific aspects of a policy decision may not be susceptible to precise determination. For example, the decision on ratifying the test ban treaty was based on weighing foreign policy, domestic political, military, and health factors. And each of these involved imponderables. How would the friendly and neutralist nations react if we refused to negotiate with the Russians? How much would the lessening of tension and possible abatement of the arms race compensate for the military risk of test cessation while the Russians are ahead of us in high yield nuclear weapons? How likely would the Russians be to catch up with us in low yield nuclear weapons by conducting underground tests which the treaty would permit? How would the "Mother" vote react to failure to approve the treaty? None of these is a scientific question.

Secondly, it is based on a misconception of the requirements for a congressional staff member who handles scientific measures. He does not have to be an outstanding scientist in a particular field. Rather, he must be a scientific generalist who can rapidly develop sufficient knowledge of an unfamiliar field to deal intelligently with matters in that area. He must be able not only to translate scientific issues into terms the layman can grasp but also to bridge the growing communications gap among highly specialized branches of science. He performs an interpretive role more analogous to that of the science writer than of the practicing scientist. He must be able to express himself with facility in speaking and writing. He should be thoroughly familiar with our system of government--especially the legislative process. And he must be aware of how science fits into policy decisions. Being a scientist is no guarantee that an individual will possess these qualifications. As Dr. Edward Wenk, Jr., a distinguished graduate engineer who has performed brilliantly in top staff positions in both the legislative and executive branches, incisively observed:

> Second, competence in science or engineering is no guarantee of competence in national political affairs. If anything, the talents, training, and temperaments involved in these two professions are quite different.[23]

In fact, when assessing the political implications of a scientific enterprise, a scientist may be handicapped because of his perspective as a scientist. For instance, many scientists tend to be somewhat contemptuous of space spectaculars, which may have far greater political impact than more solid scientific achievements. Moreover, while a scientific background is helpful, it is not indispensable A congressional staff member with the other requisites for the post can acquire sufficient expertise to cope with the technical aspects of his work.

Thirdly, it disregards the existing scientific staff capability in the Congress and available means of tapping the expert counsel of the scientific community. Many of the committees dealing with scientific measures have very capable professional staffs--a number of which have had technical training. To mention only two, the House Science and Astronautics Committee has had a core of very competent professional aides from its inception as a select committee. The high quality of the staff studies produced by them is widely recognized. In 1963, there was a first class engineer as well as a former science administrator and science writer on the regular professional staff and two engineers on detail from the armed services. The staff director of the Senate Aeronautical and Space Sciences Committee was a top-notch engineer who had an impressive record of experience as a science administrator--including managing laboratories for the AEC. Another professional staff member, who was a carryover from the antecedent select committee, had a B.S. in aeronautical engineering and a Ph.D. in psychology. In the Legislative Reference Service, the position of senior specialist in science and technology has consistently been filled by a highly competent Ph.D. in engineering or science. Moreover, the senior specialist in engineering and public works and specialists in other fields, like defense and conservation, have supplemented the committee staffs--sometimes for protracted periods--as well as performed assignments for individual Congressmen in the area of science and public policy[*].

Also, a number of committees have been experimenting with various techniques for obtaining the advice of leading scientists outside Congress. Besides the numerous committees that have employed consultants on an individual basis, a few have contracted for the services of consulting firms like the Rand Corporation. Some have organized panel discussions of experts on specific measures. And in 1960 the House Science and Astronautics Committee established a Panel on Science and Technology with a distinguished membership on a permanent basis. The committee meets periodically with this advisory panel in seminar-like proceedings. In these meetings, the panelists help to acquaint the committee with current views on broad issues in the scientific community. In addition, panel members act as individual consultants to the committee in their respective fields.[24]

There is little likelihood that the COST bill will be approved by the House even--much less enacted. At hearings on the Sibal and Widnall versions (H.R. 6866 and H.R. 3066) before the Subcommittee on Accounts of the House Administration Committee on December 4, 1963, the committee members did not display much enthusiasm toward the proposal. The almost complete lack of questions by them and the meager list of witnesses indicated that the committee was indulging in a formality rather than conducting a serious inquiry into the merits of the measure. The Senate Rules and Administration Committee has not scheduled hearings on the Bartlett bill (S. 2033) and is not likely to do so.

The chief significance of the COST bill is that it stimulated expansion and refinement of the existing arrangements for providing Congress with advice on science-related issues. Besides serving to indicate the growing dimensions of congressional concern about the problem of obtaining scientific counsel, the prospect--however remote--of the adoption of such a defective proposal prompted the search for alternative solutions as a preclusive measure.

In the hearings on testimony of scientists on space goals on June 10-11, 1963 (themselves a highly successful demonstration of how the regular hearings process can be used most effectively to obtain the counsel of nongovernmental scientists), the Senate Aeronautical and Space Sciences Committee asked every witness what he considered to be "the best type of organization and process whereby the legislative branch can obtain the kind of information needed to make decisions on policies, programs, and budgets involving scientific and technological problems." Both the Daddario and Elliott Committees have included this topic on the agendas for their comprehensive investigations of federal research programs. And the ensuing discussions have helped clarify thinking inside and outside Congress about the nature of scientific advice on public policy and the requirements for "in-house" science staff capability for Congress.

Several committees have intensified their efforts to recruit additional staff members with scientific and engineering backgrounds as well as the other qualifications for a professional aide. Encouragement has been given to developing closer cooperation between committee staffs handling scientific measures in the two chambers. And committees have been considering how to use advisory panels more effectively and experimenting with various mutations of that device.

In the legislative branch appropriations bill for fiscal 1965, the Legislative Reference Service requested eight new positions for specialists in science and technology at relatively high grades (1 GS-17, 2 GS-15, 1 GS-14, 2 GS-13, 1 GS-12, and 1 GS-9) with a price tag of $110,950.00 in order to establish a special unit to handle the work in that area.[25] The House Appropriations Committee approved the whole request. The accompanying report explained this unusual generosity in the following quaint language:

> The committee has rounded off the request, allowing $2,300,000, which will cover mandatory-type costs to maintain the current level and permit addition of 8 new research people to meet the increasing requests for service in the scientific and technological specialties . . . The committee thinks this congressional research assistance arm ought to be reasonably well equipped to meet the demands on it. Increasingly difficult questions in greater abundance are coming before the Congress as the country grows and society complexifies.[26]

On April 10, 1964, the House passed and sent to the Senate the legislative branch appropriations bill for fiscal 1965 with the entire amount for the LRS specialists in science and technology intact.

Also, the process of developing more effective linkage between Congress and the National Academy of Sciences-National Research Council was accelerated. With characteristic foresight, Dr. George B. Kistiakowsky had anticipated the demand for scientific advice for Congress. One of his motives in fostering the establishment of the NAS's Committee on Science and Public Policy (COSPP) more than a year and one half earlier was to help find a way of supplying this need. And the very able and perspicacious executive secretary of COSPP, Robert E. Green, has labored energetically and imaginatively on this task. At the aforementioned hearings on scientists' testimony on space goals, Dr. Frederick Seitz, president of the National Academy of Sciences stated that the NAS-NRC would welcome the opportunity to do more to serve Congress through its permanent staff and system of part-time consultants. In the hearings before the House Science and Astronautics Subcommittee on Science, Research, and Development on October 15, 1963, Chairman Emilio Daddario (D.-Conn.) explored this offer as the first order of business in questioning Dr. Seitz, the lead-off witness.[27] On January 3, 1964, Representative George Miller (D.-Calif.), chairman of the House Science and Astronautics Committee, announced the reaching of an agreement with the National Academy of Science to advise the Congress on science-related policy issues. Chairman Miller said that he, Dr. Seitz, and Representative Daddario had agreed in principle on the provision of certain services of the National Academy to the committee. These would include the preparation of a series of studies to be worked out between panels of the Academy and the Daddario Subcommittee. Representative Daddario said that this agreement with the Academy was one of several such arrangements which his subcommittee was working out with private and governmental groups to assist the full committee with its activities in the field of science and public policy.[28]

NOTES

The author wishes to express his appreciation to the Purdue Research Foundation for a grant which made possible three months' research on this subject in Washington, D.C., during the summer of 1963. He is most grateful to the following individuals who gave generously of their time and information in protracted interviews: Charles S. Sheldon II and Edward Wenk, Jr., Executive Office of the President; Robert E. Green, National Academy of Sciences; Eilene M. Galloway and C. Edward Wise, Jr., Legislative Reference Service, Library of Congress; Frank C. DiLuzio and Glen P. Wilson, Senate Aeronautical and Space Sciences Committee staff; and W. H. Boone, John A. Carstarphen, Jr., Richard P. Hines, and Philip B. Yeager, House Science and Astronautics Committee staff. Because most of the persons interviewed requested that any information they furnished not be attributed specifically to them, footnote references have not been made to interview sources unless an individual has been directly quoted in the text. Finally, none of these persons nor the Purdue Research Foundation is responsible for the views expressed in this paper.

[1] Government and Science: Their Dynamic Relation in American Democracy (New York: Galaxy Book, Oxford University Press, 1962), pp. v-vi.

[2] The statistics in the preceding two paragraphs are from U.S., Congress, House Committee on Science and Astronautics, Fiscal Trends in Federal Research and Development, committee print, 88th Cong., 2d Sess., Feb. 26, 1964, pp. 3-6.

[3] *Congressional Quarterly Weekly Report* (cited hereafter as *CQ*), Vol. 21 (Jan. 18, 1963), p. 52; *ibid*., (Mar. 15, 1963), p. 326; *ibid*., (Dec. 6, 1963), p. 2133; *Science*, Vol. 141 (Sept. 20, 1963), p. 1163.

[4] *Science*, Vol. 142 (Nov. 22, 1963), p. 1044.

[5] *The Reporter*, Vol. 29 (Sept. 26, 1963), pp. 20-26.

[6] Figures supplied by Dr. Edward Wenk, Jr., in personal interview on Sept. 5, 1963.

[7] *Report of the Committee of Enquiry into the Organisation of Civil Science*, Command Paper 2171 (London: Her Majesty's Stationery Office, 1963).

[8] *Science*, Vol. 142 (Oct. 18, 1963), pp. 372-73.

[9] *Science*, Vol. 143 (Feb. 21, 1964), pp. 786-88; *ibid*., (Feb. 28, 1964), p. 919; *ibid*., (Mar. 13, 1964), pp. 1146-48; *New Scientist* (Nov. 7, 1963), p. 301; *Nature*, Vol. 200 (Dec. 21, 1963), p. 1133.

[10] *CQ*, Vol. 21 (Mar. 15, 1963), p. 315.

[11] U.S., Congress, House, Committee on Government Operations, *Health Research and Training: The Administration of Grants and Awards by the National Institutes of Health*, House Report No. 321, 87th Cong., 1st Sess., Apr. 28, 1961, pp. 72-75.

[12] U.S., Congress, House, Committee on Government Operations, *Administration of Grants by the National Institutes of Health (Reexamination of Management Deficiencies)*, House Report No. 1958, 87th Cong., 2d Sess., June 30, 1962, pp. 8-9, 27, 30.

[13] U.S. Congress, House, Committee on Government Operations, *Hearings on Health Research and Training*, 87th Cong., 1st Sess., Aug. 1, 1961, p. 2.

[14] House Report No. 1958, 87th Cong., pp. 10, 42.

[15] As quoted in *Science*, Vol. 140 (June 7, 1963), p. 1076.

[16] House Report No. 1958, 87th Cong., pp. 11, 50-51.

[17] *Ibid*., pp. 13-14, 25.

[18] *Ibid*., p. 21.

[19] *Ibid*., p. 26.

[20] *CQ*, Vol. 21 (May 31, 1963), p. 844.

[21] *Science*, Vol. 140 (May 17, 1963), p. 795.

[22] U.S., Congress, House, Committee on Appropriations, *Departments of Labor and Health, Education, and Welfare, and Related Agencies Appropriation Bill, 1964*, House Report No. 246 (to accompany H.R. 5888), 88th Cong., 1st Sess., Apr. 25, 1963, pp. 25-26. Also, see *CQ*, Vol. 21 (May 31, 1963), pp. 845-46, and *Science*, Vol. 140 (May 3, 1963), pp. 467-68.

[23] U.S., Congress, House, Committee on House Administration, *Hearings on Establishment of a Congressional Science Advisory Staff*, 88th Cong., 1st Sess., Dec. 4, 1963, p. 68. See also, James L. McCamy, *Science and Public Administration* (University, Ala.: University of Alabama Press, 1960), pp. 172-73.

[24] U.S., Congress, House, Committee on Science and Astronautics, *Panel on Science and Technology, First Meeting*, House Report No. 1587, 86th Cong., 2d Sess., May 4, 1960, pp. 11-12; *ibid.*, *Panel on Science and Technology, Fifth Meeting*, committee print, 88th Cong., 1st Sess., Mar. 27, 1963, p. 1.

[25] U.S., Congress, House, Committee on Appropriations, *Hearings before a Subcommittee on Legislative Branch Appropriations for 1965*, 88th Cong., 2d Sess., Mar. 18, 1964, pp. 279-82.

[26] U.S., Congress, House, Committee on Appropriations, *Legislative Branch Appropriation Bill, 1965*, House Report No. 1307 (to accompany H.R. 10723), 88th Cong., 2d Sess., Apr. 7, 1964, pp. 15-16.

[27] U.S., Congress, House, Committee on Science and Astronautics, *Hearings on Government and Science*, 88th Cong., 1st Sess., Oct. 15, 1963, pp. 32-33.

[28] Press release from House Committee on Science and Astronautics, dated Jan. 3, 1964.

GPO 881-280

INFORMATION REQUIRED BY PARLIAMENTS IN A WORLD INCREASINGLY DEPENDENT UPON SCIENCE

(An address before the Interparliamentary Union Conference, Geneva, Switzerland, Nov. 5, 1965, by Edward Wenk, Jr., Chief, Science Policy Research Division, Legislative Reference Service, Library of Congress)

Mr. President, Mr. Secretary General, ladies and gentlemen, it is a very great privilege to have been invited to participate in this symposium of the Interparliamentary Union. And it is all the more an honor to represent the scientific community at this auspicious dedication of the Union's new home.

The long history and high purpose of this body in seeking world peace and enhancement of the democratic process are well known. Especially in Geneva, the city of peace, I felt it all the more appropriate to recall the basic relationships of science and politics that constitute the theme of my assignment. Science knows no national boundaries. In a troubled world, communications between scientists have often supplemented and aided international understanding when political solutions seemed remote.

In the United States, we have a long tradition of recognizing that politics and science mix. Benjamin Franklin and Thomas Jefferson actively sought advancement and applications of science to serve public purposes—then to help a newly developing nation.

Science and the democratic process were found to blend easily. They still do today.

Both reflect a common striving for progress; both test emerging truths through the process of critical inquiry; both are subject to constant revision and to revitalization—not by edicts of a few but by contributions of many.

We recognize more today than ever before, however, that science is itself passive. Even technology is amoral, for the deliberate use of science for practical purposes may produce adverse as well as beneficial effects. What results depends much more on decisions of the politician and parliamentarians than on decisions of scientists or engineers. This, in fact, is science policy.

We are then faced with the question of what information is required for policy decisions.

If all history were recorded, we would probably find that emperors and empires failed for want of some specific piece of information. In our own technological era, satirists picture governments going down to defeat, or at least paralyzed not by too little information but by too much.

The scientific world also views with alarm problems arising from an exponential growth in literature that seems to propagate faster than a colony of rabbits. This topic of "Information Required by Parliaments in a World Increasingly Dependent Upon Science" thus invites opportunities to view the double calamity when two information-rich universes meet.

Rather than deal with the obvious, I should like to pose the thesis that additional burdens imposed on representative government by questions of public policy involving science can be met by the improved quality and structuring of information for deliberation and decisionmaking. And although this notion is discussed with principal reference to the U.S. Government, we may find a note of optimism: that all parliaments may find science a source of remedies as well as of problems—a means for fulfilling their modern basic functions in a democracy.

SCIENCE CONFOUNDS POLICYMAKING

Every parliament has a fundamental need for information to aid in the making of intelligent choices. The growing agenda about science and technology has sharply intensified that need. The pace of scientific discovery and engineering application has accelerated. Subject matter has become more complex. Relationships among Government, universities, and private enterprise have become more intertwined. Budgets have grown sharply, and policy decisions affect more people, more quickly and more continually than ever before.

To make these decisions, we have a critical need for information that is authentic, complete, and timely. And it must be available in a form suitable for comprehension and employment by a policymaker.

Delegates to this symposium of the Interparliamentary Union do not need to be reminded that the primary involvement of parliaments with science arises not from science for its own sake, but from the potential contribution of science to serve society. We know from recent experience that technology and science may strengthen national security, stimulate economic growth, provide food and fiber, counter disability and disease, and alter the qualities of natural environment.

This last concern refers not only to chemical pollution of air and water, but also to esthetic pollution of our cities from urban crowding amidst tasteless architecture, and acoustical pollution from noise. We have learned from the energetic application of science to military affairs that the consequences of science are critically influenced by policy decisions in the public domain. Thus, to maintain an environment salubrious to both body and spirit, the policymaker must seek a continuous partnership with science.

FIVE CLASSES OF ISSUES

Science-related decisions by the policymaker involve five classes of issues: (a) identifying goals; (b) assigning priorities between competing goals (usually through appropriations); (c) determining the scope and direction of Federal involvement, in relation to State and private initiatives; (d) matching manpower, facilities, and information transfer facilities to goals, and (e) designating responsibility and authority to Federal agencies. All of these steps may be influenced by opportunities afforded by science.

INFORMATION ILLUMINATES ALTERNATIVES

Information about progress through science is then needed for three functions: to illuminate alternatives; to provide criteria for choice; and to facilitate political strategy.

The first role of information is to illuminate choices—not scientific choices, but political choices. Here, considerations of science must be integrated with economics, political processes, domestic and social policies, and institutional relationships.

Because resources are inevitably limited, choices must be made between alternative goals—as between funds for manned exploration of Mars or an accelerated search for cancer cure. Choices must be made between alternative means to reach the same goal—such as between manned bombers or submarine-based missiles.

INFORMATION PROVIDES CRITERIA FOR CHOICE

Information also forms the basis of rational criteria for choice. Cost-effectiveness indexes comprise one set of yardsticks for which data are required to assess both the costs and the benefits. As methodology for long-range planning improves, criteria will take into account total as well as initial costs, and also manpower requirements. Effects on society will also become a factor in choice, more and more amenable to rational actions as we conduct research in behavioral sciences as intently as we do in the natural sciences.

What is an acceptable level for sonic boom? Someday, we may adopt quantified criteria for such political questions in a democracy, based on the proposition that actions in the long run must increase options for the greatest number of individuals.

INFORMATION FACILITATES STRATEGIES

Every policymaker knows that correct decisions depend as much on timing and on effective implementation as on the original choice. Such a decision thus depends on balance between short-range and long-range factors, between investment and opportunistic exploitation. Because of the high costs and high risks that attend development of say a new supersonic transport or nuclear powered ships, there is clearly a need to avoid premature decisions. To defer commitment, to maximize options, to make the U-turn when at a deadend street, are well-known strategies for the effective exercise of political power and responsibility. All of these qualities of flexibility become more viable in the presence of scientific facts.

TYPICAL SCIENCE POLICY ISSUES

This informational framework for policymaking assumes real dimensions when considering science policy issues concerning both "ends" and "means." The first session of the 89th Congress was confronted with such questions as: authorizing of $5.4 billion for space exploration; long-range planning for space activities following the 1970 manned lunar landing; establishing goals for marine exploration and resources development, and improving coordination of 20 agencies engaged in oceanography; abating air pollution; expanding fresh water resources; conducting research on and developing a supersonic transport and high-speed rail transportation between Boston and Washington; establishing a new Environmental Science Services Administration; specifying requirements for academically related basis research, and for support of graduate students; defining needs to increase the number and geographical distribution of centers of research and educational excellence; facilitating the transfer of science to civilian-based technology; defining criteria for site selection for a new 200 Bev accelerator; studying economic implications of U.S. conversion to the metric system; appropriating over $16 billion for federally sponsored research and development, nearly half related to military security, but an even larger amount devoted to such technology-based activities as public works.

The list only suggests the diversity and complexity of questions involving science and technology—the relevance to a vast number of public purposes that become reflected, incidentally, in the jurisdiction of a large number of different congressional committees.

CONGRESSIONAL CONCERN FOR ADEQUATE SCIENCE ADVICE

In the United States, the White House moved late in 1957 to meet the unprecedented challenge of science-based issues. The President has now available a four-component advisory apparatus of experts: the office of Special Assistant to the President for Science and Technology and the President's Science Advisory Committee; in 1959, the Federal Council for Science and Technology; and in 1962, the statutory Office of Science and Technology.

These initiatives found our Congress, already "outmanned and outgunned," at an even further disadvantage in maintaining some degree of parity in technical competence for policymaking. The Congress is continually the target of much unsolicited information. Some information originates from parties at interest, some from the executive branch. Frequently, the information is flavored by advocacy. While such contributions are essential to democratic political process for the Congress to be a mirror of consensus, the purification of information by impartial analysis, "to separate the signal from the noise," vastly increases value of information to the policymaker.

In 1963, Senators MONRONEY, ANDERSON, and BARTLETT, and Congressmen MILLER, DADDARIO, and Sibal, proposed a variety of steps that ranged from strengthening existing staff elements to creating entirely new legislative agencies patterned after the Office of Science and Technology.

All of these proposals reflect the desire for better rather than more science-related information. Even more significantly, these proposals implied informational resources made more useful through analysis. Decisionmakers always want access to raw data—but they now demanded access to powerful staff resources where the only loyalty is to objective interpretation. By this means, the Congress, like the President, may ask the right questions.

STRENGTHENED SOURCES OF INFORMATION

Many new sources have been developed. The Congress now looks to the President's Office of Science and Technology for governmentwide information on such interagency programs as weather services, oceanography, and science information. Otherwise, in crossing agency lines and committee jurisdiction, these programs tend to be fragmented so as to go beyond rational assessment.

The Congress also looks to the National Science Foundation as a source of statistics and analysis concerning funds for research and development, scientific and technical manpower and facilities. Such data are categorized so as to show the distribution by field, by agency, by performer, and even by geographical distribution.

The Congress has also recognized the function of the National Academy of Sciences to advise the Congress as well as the executive branch on special topics, but especially on the needs and opportunities of science itself. A new Academy of Engineering may soon be an additional source of counsel.

Congress has long sought the advice of competent outsiders. Greater use is being made of expert witnesses whose testimony is solicited singly or in concert to explain implications of scientific developments, rather than to invite a position on an issue.

These sources are increasingly effective as the Members inform themselves in order to break through the monolithic views of administration witnesses, and to identify alternatives from which the final decision was made—a decision often propounded with such energy as to make it appear that only one choice was available. Ultimately, however, the Congress has had to reinforce its own committee organization, its committee staff, and the Legislative Reference Service of the Library of Congress as primary resources for gathering facts, for helping to identify issues, for obtaining testimony at hearings, and for identifying pros and cons of alternative actions.

NEW CONGRESSIONAL COMMITTEE

When congressional apprehension rose in 1963 over the lack of control over growing research budgets, the House established a new Select Committee on Government Research. In its 1 year of operation, it developed a broad base of statistics and findings primarily on administrative elements of Federal research and development. Interestingly enough, its major recommendation for action applied to the Congress rather than to the Executive—to establish a new Joint Congressional Committee on Research Policy.

And also established in 1963 was a new Subcommittee on Science, Research, and Development, chaired by Congressman EMILIO Q. DADDARIO, one of the U.S. delegates to this symposium. His subcommittee opened with a series of "posture" hearings, and has continued even more intensified activity since. During this first session, the subcommittee held hearings on the present and future role of the National Science Foundation to assure the quantity and quality of the Nation's science resources to meet foreseeable national needs. Amendments to the Organic Act are being prepared.

In the 89th Congress, a new Subcommittee on Research and Technical Programs was established in the House Government Operations Committee under Congressman HENRY REUSS that has focused on conflicts between Federal research and education. A Senate Subcommittee on Employment and Manpower under Senator GAYLORD NELSON held extensive hearings on the implications of undue localization of Federal research funds, while a new Subcommittee on Government Research has been established under Senator FRED HARRIS with a yet undisclosed agenda.

As suggested by the sample of actions of the 89th Congress mentioned earlier, many substantive and appropriation committees have been looking at how science serves explicit public purposes.

SCIENCE POLICY RESEARCH DIVISION

The major new step to expand the base of information and advice needed by the entire Congress to deal with science-related issues was establishment of the Science Policy Research Division (SPRD) in the fall of 1964. Following patterns enunciated through the LaFollette-Monroney Reorganization Act of 1946 in such fields as international affairs, conservation, and social welfare, this new unit was established in the Legislative Reference Service by appointment of a number of technical specialists to serve all Members of both parties and all committees. The division deals with two sets of issues: concerning deliberate exploitation of scientific discovery to serve public purposes, and concerning the allocation or development of funds and manpower required to fuel the Nation's scientific enterprise.

Emphasis in the new unit was placed more on policy-type research than on reference-type inquiries and 1 year of operating experience strongly confirms congressional interest in utilizing this new capability at its highest intellectual potential. In operating terms, it functions much like the President's Office of Science and Technology. Issues are virtually the same. The main difference lies in SPRD having to avoid partisan advocacy and in having no responsibility to operate as does OST in carrying out coordination of interagency programs for the President.

During its first year, the division received more than 600 legislative-related inquiries—from 48 different Senators and 105 Congressmen, and from some 16 standing subcommittees in the 2 Houses. Assistance was furnished for 8 different committee hearings; 60 analytical studies were prepared, 10 of which were of 75 or more pages. Two major studies have been released with acknowledgment of SPRD authorship: "Government Weather Programs," a report of 203 pages for the House Committee on Government Operations, and "The National Science Foundation—a General Review of Its First 15 Years," a report of 286 pages prepared for the House Science and Astronautics Committee. The division also filled 30 requests for major addresses or statements; 175 for personal consultation; 118 for factual materials. It monitored over 450 requests for scientific information unrelated to policy.

NEW TECHNIQUES

One of the most important functions of the new division in dealing with science policy is the structuring of information to reveal relationships that often escape notice but that become increasingly significant because of implicit if not explicit impact of a decision on elements not conspicuously related to the issue. Arrays of facts make visible the inconsistencies between policies and programs of different agencies; time series show trends of budgetary commitments where past decisions may preempt future options.

This approach has been extended to become a systems analysis mode of problem solving. And here, it becomes possible to treat in a policy sense all elements related to one objective, for example, such as low-cost transportation. Otherwise, treatment as single elements of rail, ship, and/or truck could result in contradictory and self-defeating policies. A similar treatment proves necessary when dealing with management of human ecology where goals of high agricultural productivity enhanced by use of pesticides collide with other goals of protecting human health.

These steps—from fact, to one dimensional interpretation of fact, to a multidimensional analysis—are essential if information for science-based questions is to receive maximum utility.

NEW TOOLS

A collateral step yet to come is to employ modern automatic data processing equipment to store and retrieve selectively such facts as may be desired and, through experimental permutations, to search for subtle relationships not otherwise readily disclosed. Such equipment has been proposed to facilitate housekeeping chores of legislatures—to permit rapid readout of budget data or to determine status of pending legislation; to record votes, or to locate documents as their numbers increase. But such equipment also makes it possible to keep track of contract awards, the status of the Nation's manpower—and to test on paper through techno-economic models the quantitative merits of alternatives, say between two techniques for flood control. Such tools will be no panacea for dealing with science-related issues, but they will help meet problems of complexity and change, especially to permit a legislature to meet the expertise of the executive branch with some informed but independent judgments of their own.

Such tools must be servants, not masters. They should not be permitted to hasten the political process beyond the speed of human deliberation, or beyond the rate of reciprocal communication between parliaments and the grassroots of consensus.

Staff of a very special kind are required for legislative research and for effective employment of new informational tools dealing with science. Expertise in scientific disciplines is necessary, but not sufficient. Other background is necessary in legislative process, public law, economics, foreign affairs. Personal qualities are required of objectivity and ability to sense and solve problems, think logically and structure ideas. Staff are needed who combine muscular skepticism with a humanistic approach to science and technology—who, like the language translator, must speak two languages—that of science or engineering, and that of politics.

Blending science with public policy is so new that no readymade academic training ground exists for recruitment. Also, most candidates in this area began their professional development "at the bench" and usually view policy research as a diversion from their career. It has thus been necessary in the Science Policy Research Division to develop new policy staff at the same time that the analytical needs of the Congress were being satisfied.

NEW CONGRESSIONAL INITIATIVES

The 89th Congress has developed a new confidence in dealing with these issues in science and technology. There has been selective, critical probing; review of arguments of the Executive; action to end fence straddling, for example in a move toward more institutional grants for research as compared with project grants.

In the case of oceanography, the Congress has taken initiative over a wide front of action ranging from improved coordination to establishment of marine exploration as a new public purpose.

But involvement of the U.S. Congress in science policy affairs is intensifying, because the issues themselves are changing: after a vigorous growth of Federal science mainly to serve military security needs, more stabilized international relations and the growing concern about economic and social problems are accelerating a transition to a new mode of Federal technology. The present plateau in U.S. spending for research and development provides an opportunity to build a far more durable base for the present science-technology enterprise. A major problem, therefore, arises on how to employ and dispose the capabilities developed for security objectives for the continued benefit of man, how to integrate this composite of ideas and talent with the other significant elements in a free enterprise, pluralistic society of capital and entrepreneurship which have been the key to vigorous extension of our democratic ideals.

We thus pose a new set of science policy issues that pivot on the old questions of "Whether?" and "How?" Such questions were historically raised in relation to the scientific projects of military significance. But these past decisions did not have the economic, legal, and geopolitical implications of those being raised today.

Because the new issues cannot be handled on faith, protected by necessary considerations of military security, the funding and the legislative actions on science-related issues in the future must be far more carefully tuned to public support than may have been possible in the past. The Congress may extend its activities to new areas as they have previously in agricultural and health research. Recent action in the water resources, transportation, and pollution fields may well signal this trend.

To accomplish this transition, however, the U.S. Congress, as a mirror of consensus, is expecting to play an even stronger role in linking science to public policy, in blending engineering, economics, law and politics, funds and organization—the essential ingredients of technology. Federal structure for science and technology, at all levels, is being evaluated to update missions and roles, and legislation is being considered to meet the rapid obsolescence of science-based Federal agencies. But special interests and the general public must become better informed and more energetic participants in the democratic system, by conducting science policy research of their own.

SUMMARY

If parliaments are to maintain their basic functions in a democracy, they must provide for science to serve society. Better information is needed in dealing with science-related issues in order that they fulfill their coordinate role in policymaking—to identify public purposes; assign priorities; determine scope of Federal involvement; match resources to goals; and assure prudent Federal management. Such information must reveal alternatives of action as well as the criteria for choice and appropriate political strategies.

What we need is better information—not necessarily more. We must draw on the entire base of scientific discovery and on technology. We must also draw on the body of literature dealing with economics, law, public administration, and foreign affairs. Numerous devices to elicit information are available. But for information to be of maximum value for use by policymakers, it must be structured, analyzed, and arrayed to reveal complex, subtle, yet vital, relationships.

While these analyses for parliaments draw primarily on contributions of authorities in many fields, they may require a new family of staff resources. In the United States, a Science Policy Research Division has been established to serve the U.S. Congress. Its functions are similar to those of the President's Office of Science and Technology. But here, a policy research staff has been insulated from political involvement so that as advisers, their only loyalty is to professional objectivity. Their main role is thus to help the Congress ask the right questions.

Modern automatic data processing equipment and new information handling techniques will be increasingly utilized to meet the complexity and pace of modern decisionmaking. But these tools must never be viewed as substitutes for shrewd, informed political judgment.

Finally, in a representative government, it is increasingly apparent that parliaments must be not only recipients of science-based information. Parliaments must also be the source of information and interpretation—to illuminate the issues and alternatives before the Nation. Only by this step can we assure adequate exchange of views with the constituency, for parliamentary action to indeed be "the people's choice."

SCIENTIFIC CHOICE, BASIC SCIENCE, AND APPLIED MISSIONS

by Alvin M. Weinberg
Oak Ridge National Laboratory

Introduction

My purpose in this essay will not be to answer directly the two questions concerning scientific choice put by the House Committee on Science and Astronautics. Rather, I shall try to outline a way of looking at the question of scientific choice which I believe both clarifies the issue and diminishes the magnitude of the problem. What I hope to contribute is a point of view that will help our Government allocate resources to science more rationally, rather than any specific suggestions as to what such allocations should be.

The questions posed by the House committee assume implicitly that "Support of Science as a Whole" is a useful subclassification within our Federal budget, and that we must be prepared to make allocations within an overall science budget for all scientific and engineering activities. I, along with many others, believe that lumping all science and technology together is misleading. The same considerations that militate against a single Department of Science militate equally against putting support of all science in one compartment of the budget. I shall therefore propose a different and, I believe, more rational way of dealing with questions of choice and magnitude of support of science; and I shall indicate how this could influence our governmental organization for science (*1*).

One overriding practical problem emerges from my analysis. This has to do with the predicament of our expanding basic research enterprise in the physical sciences. Until now U.S. basic research in the physical sciences has been supported largely as an assessment or "overhead" charged against mission-oriented agencies, such as the Atomic Energy Commission and the Department of Defense. These agencies, whose primary missions lie outside science, have fairly stationary budgets; they can hardly be expected to underwrite the expansion in basic research that most of our physical scientists consider desirable. This expansion, if it takes place, will therefore have to be charged to the Government agency whose primary mission is the support of science—that is, the National

Science Foundation. Whether or not basic physical science continues to flourish will therefore depend largely on whether or not Congress encourages the growth and vigor of the Foundation. Expansion of the National Science Foundation is perhaps our country's central political problem related to the support of science.

I. *Political and Administrative Choices*

As a prelude to addressing the problem of scientific choice, I digress into political philosophy to distinguish between what I call political choices and administrative choices. Political choices define the national interest; administrative choices implement political choices. Congress, with the strong concurrence of the President, determined in 1941 that it was in the national interest to declare war; this was a political choice. The President and the Armed Forces, with the concurrence of Congress, decided how to fight the war; this was an administrative choice. Congress decided in 1961 that it was in the national interest to send a man to the moon; the National Aeronautics and Space Administration determined that the lunar orbital rendezvous with a Saturn-boosted launch was the way to achieve this goal.

In practice, political and administrative choices are not so sharply separated. Congress greatly affects administrative choices through its control of the purse strings. The Executive obviously influences political decisions, although Congress has the last word in drafting legislation.

The problem of choice is not so much who makes political choices and who makes administrative choices: It is rather that choices should be made among political alternatives or among administrative alternatives, not among political and administrative alternatives. We should not choose between an end and a means to achieve an end: Whoever makes choices should choose between different ends or between different means to achieve the same end.

Allocation of some of our science budget involves administrative choices; allocation of other parts involves political choices. Therefore choosing among alternatives from "all of science" confuses political choices with administrative choices.

II. *Basic Science and Applied Science*

This digression into political philosophy is relevant to the issue of allocation of scientific effort, the root problem the Miller committee wishes us to consider. For, insofar as applied science is merely a means to a nonscientific end, the allocation of our applied research and development budget involves administrative decisions, whereas allocation of our budget for pure science—science which is done for its own sake and is therefore an end in itself—involves political decisions.

An example will clarify the matter. Suppose we decide, as a matter of national policy, to spend several million dollars to help India control its population explosion. This is a political decision. In carrying out such a decision many alternatives are available. We could spend all the money to get up an old-age insurance system to reduce the economic incentive for Indian women to have more children. Or we could spend most of the money on scientific research, some of it fairly basic, to enlarge our knowledge of the physiology of reproduction in the hope that such knowledge would eventually help India control its population. Here we must choose between two strategies—one involving science, the other not involving science—for achieving the same end. The choice of the better way to achieve the end—whether science or "operations"—is an administrative decision, not a political decision. It must therefore be made primarily by the agency responsible for helping India control its population. Moreover, money spent on biological research which, in the judgment of the responsible agency, is needed to cope with India's population problems should not be part of our science budget: Such funds should be part of our foreign aid budget. We do not argue about how much the Government spends for transportation as a whole, or accounting as a whole, or legal advice as a whole. These activities in every instance are carried out not for their own sake, but to further some other politically defined objective. The expense of science as a means to achieve a nonscientific end should logically be assessed against the budget for achievement of that end, not against some mysterious budget labeled "Science as a Whole."

Some science that is relevant to population control may be rather basic—for example, the study of how progesterone affects DNA synthesis. Nevertheless, if the science is motivated by a desire to achieve a certain end outside of science, then it should be judged against other, nonscientific, ways to achieve that end: It should not be judged against other science, such as ecology or group theory, that is done either to achieve a different nonscientific end or merely for its own sake.

Insofar as we can identify elements of the science budget that are pursued for some purpose outside of science, we have succeeded in reducing the size of the problem of choice with which Congress is concerned. The choice then is left to the agency responsible for achieving the political end: if the agency decides that more science rather than more transportation is a better way to achieve its mission, the decision may still be questioned by Congress, but not on the basis that one should spend more for a different kind of science having nothing to do with the mission of the agency.

There remains a residuum of science which really is pursued for its own sake. More accurately, there is a gradation of science from the heavily applied (which is so recognized by those conducting the research) to the very pure (again as viewed by its practitioners). I shall assume for the moment that we can decide what is applied and what is basic, though in some cases such a decision is the essence of the problem. Support for applied science would be assessed as an expense against the end we seek to achieve, as I have suggested above. The remaining basic sciences, pursued primarily for reasons that are intrinsic to science itself, would then be properly included in a budget which I call the "Intrinsic Basic Science Budget."

This activity of our society, intrinsic basic science, should properly be balanced against other activities of the society—for example, education and foreign aid. As I see it, the choice between intrinsic basic science as a whole and other, nonscientific, activities is the primary relevant political decision. However, since the basic science budget is relatively small—perhaps $1.5 billion—the problem before the country is considerably smaller than one might expect.

What I say suggests that our habit of putting together our expenditures on all science has obscured the real issue. Though I am not advising that we never look at our science budget as a whole, I suggest that this not be done with an idea of making adjustments between money for basic science and money for applied science.

I believe that by realistically identifying science that is done to accomplish a nonscientific—i.e., politically defined—mission, and separating it from science that is done just for its own sake, we can simplify many of the problems of scientific choice that the Congress is worried about. The real business at hand is to decide realistically and honestly what science is done to achieve a nonscientific mission, and what science is done largely because it seems intrinsically interesting and significant to its practitioners. It would be most illuminating to examine the scientific program of each of the agencies, and to tabulate how much of its scientific work really is mission-oriented and how much is basic. I suspect that the scientific work of at least some of the agencies tends to become relatively less mission-oriented as the years go by. This is certainly true of the Atomic Energy Commission. When the Commission took over from the Manhattan District, most of what it did scientifically was directly related to the development of nuclear energy. As the years have gone by, the fraction of research less directly relevant to the mission of the Atomic Energy Commission has expanded—or, perhaps better, the mission of the Commission has been reinterpreted to include support of basic research itself—even basic research that is fairly remote from nuclear energy and its byproducts.

The task of making such an inventory will be difficult, especially since many researchers, if pressed, can find a connection between what they do and the mission of whatever agency is paving their way. Nevertheless, I believe that the National Academy of Sciences and its Committee on Science and Public Policy have a fine opportunity to make this inventory through the panels that are now reviewing different fields of science and projecting their future needs and growth. Each panel reporting on basic science ought to identify, for each major proposed expenditure in basic science, the applied science or development that this basic research supports, and the fraction of the budget for the relevant agency mission represented by this field of basic research.

In judging how much basic science "overhead" an agency can afford, many complicated but rather obvious issues are raised—like degree of relevance to the agency's mission, promise of progress, and so on. The main point is that wherever a tie-in with an applied science can be made, one has a clue, derived from the original political decision defining the importance of the applied science, as to the importance of the related basic science, and the level at which the public ought to support it.

The view I express—that to bring order to our thinking about public support of research it is first necessary to separate research done to achieve a nonscientific end from research done to further science—is a very old one. I am only urging that we really do make this separation rather than just talk about it. Had Congress originally realized that the money devoted each year to science for its own sake was about $1 billion, and not $16 billion, I doubt that there would have been so much concern about expenditures for science.

III. *Relation between the National Science Foundation and Other "National Science Foundations"*

The tendency of mission-oriented agencies to do basic research that is relevant, though only remotely, to their missions has in a way defeated the original design for the National Science Foundation. For now we have eight or nine "National Science Foundations"—the National Institutes of Health, the Atomic Energy Commission, the Armed Services, and others. Almost every agency now supports extramural research that is only remotely relevant to its mission.

This mode of support can be justified on the grounds that basic research in a field is necessary for doing related applied research. The cost of the basic research is properly to be added to the cost of achieving the nonscientific end that justified the applied research in the first place. For example, our country in 1961 decided to send a man to the moon. How much our country can afford to spend on this venture is a political decision: it must compete with foreign aid, veterans' benefits, farm subsidies, and other major governmental activities. To send a man to the moon requires a vast scientific and technological effort; obviously most of the science is heavily applied. At least some of the scientific work falls in the field of astronomy—but mostly solar astronomy, not stellar astronomy. Nevertheless, I believe stellar astronomy is sufficiently related to solar astronomy, and progress in stellar astronomy has enough fallout in solar astronomy (both directly and indirectly, through students, techniques, etc.) that it can be considered a proper assessment against the cost of solar astronomy and therefore against the cost of the moon shot. Thus I can see a justification for making the National Aeronautics and Space Administration a little National Science Foundation for basic stellar astronomy; and, moreover, I can see that the National Aeronautics and Space Administration ought to support considerable stellar astronomy as a fraction of its budget for solar astronomy.

In the same way, I would argue that each mission-oriented agency should assume the responsibility for supporting basic science in fields generally relevant to the agency's applied science, *at a level which bears some relation to the size of its applied science budget.* Thus, basic botany might be supported by the Department of Agriculture, acting as a sort of National Science Foundation for botany, and its support for basic botany would depend on the money available for applied agricultural research; basic physiology would be supported by the National Institutes of Health in the same spirit, and so on. The point is that the level at which mission-oriented agencies support relevant basic research should be related to the level of the applied research that they feel they must do to accomplish their missions. This basic research is a tax, assessed against every agency using science as a means to accomplish its mission.

How big the basic research assessment should be will vary from agency to agency. The amount of such support probably should be geared to an estimate of just how much the agency's applied mission derives from past basic research—for example, the Atomic Energy Commission, the National Aeronautics and Space Administration, and the Department of Health, Education, and Welfare should spend a large fraction, like 10 percent, of their budget on basic research, and other agencies perhaps proportionately less. In practice, this judgment, though made primarily by the agency, would undoubtedly, and properly, be reviewed by the President's Science Advisory Committee and the Office of Science and Technology, as well as by Congress. This support for basic research would be regarded as repaying a debt—a replenishing of the well—so that other similar endeavors will have something to draw on; it should also be regarded, in part, as work expected to pay off in a rather tangible but unpredictable way.

In many cases, the fraction of its applied budget that an agency is willing to devote to relevant basic research will be less than the scientists in the fields involved think they require to keep their fields healthy (as evidenced, for example, by proposals that cannot be funded). Here is where the National Science Foundation must find its primary function: The Foundation should be the agency that supports basic research, even in the fields that are supported by the mission-oriented agencies, *at levels over and beyond what the mission-oriented agencies think is proper for the accomplishment of their missions.* This function of the National Science Foundation was recognized in Executive Order 10521 dated March 17, 1954—some 4 years after the National Science Foundation was established:

> As now or hereafter authorized or permitted by law, the Foundation shall be increasingly responsible for providing support by the Federal Government for general-purpose basic research through contracts and grants. The conduct and support by other Federal agencies of basic research in areas which are closely related to their missions is recognized as important and desirable especially in response to current national needs, and shall continue.

Thus, suppose the National Aeronautics and Space Administration agreed to support stellar astronomy, but at a level only one-third as great as the astronomers believed to be scientifically justified. This is understandable, since the National Aeronautics and Space Administration's interest in stellar astronomy is somewhat peripheral. The National Science Foundation could then step in with the money needed to support astronomy for its own sake, beyond the level needed to assure success of the missions of the National Aeronautics and Space Administration.

In some cases the National Science Foundation would decide not to support a field beyond the level supported by a mission-oriented agency. This is perfectly proper. The Foundation would, in effect, be making a choice between different fields of basic research, all of which have to be supported within a total budget for "science for its own sake," and the pursuit of each of which is an end in itself.

The primary political decision involving science for its own sake would then amount to determining how much the National Science Foundation, the custodian of science for its own sake, gets from Congress. The criteria of choice the Foundation would use in making judgments between different fields could be those in my article, "Criteria for Scientific Choice," (2) or other similar criteria; they would include both internal and external criteria, as described there, but the criterion of technological merit would probably be given relatively little weight. In this respect the National Science Foundation would weigh its criteria of choice differently than would the mission-oriented agencies, since the latter would use relevance to their missions as a primary criterion.

I realize that the position I espouse places the bulk of the motivation for support of basic research on some hope of eventually obtaining applied benefits. This is as opposed to support of basic research for its cultural value—the pleasure it gives people to read about and understand new discoveries. I now think the expectation of eventual technical benefits to society is the firmer basis for support and is entirely suitable, provided one does not expect the benefits to be too direct too soon.

IV. *The Coming Crisis in Support for Basic Physical Research*

The line of thinking I have described (for which I certainly claim no originality) provides a key to how we deal with part of the second question put by the Miller Committee: How do we allocate support within an overall increasing or decreasing science budget? My scheme does not directly answer this question; instead, it proposes a pattern of organization (in Congress as well as in the executive branch) for dealing with the question.

According to these views, the basic science budget that supports mission-related activities (either in the sense of "pay-off" or "repayment of debt") is part of the budget for accomplishing the mission. To some extent it goes up or down as Congress decides that the mission of the agency deserves more or less support; or as the management of an agency and its advisers decide that the science is more or less germane or otherwise worthy of its support. It can be argued that this places basic research at the mercy of mission-oriented people who may have little concern for basic research. But I do not see this as all bad. For this basic research is supported in the first place because of its relevance to the agency's mission, and it is inevitable that if the agency's mission is downgraded so will be the basic research performed to support that mission. Each activity aimed at accomplishing an agency's mission should have as much a priori chance to argue for its piece of the total agency "pie" as every other. Nevertheless, I see two justifications for basic research receiving better treatment from its supporting mission-oriented agency than, say, development, in a time of falling budgets. In the first place, basic research is usually a more specialized scientific activity than is development; basic researchers cannot move as easily from one task to another as can development engineers. For this reason basic research suffers relatively more from stop-and-go funding than does development. It is easier to remobilize quickly around a specific applied project than around a highly specialized basic research project. In the second place, basic research done by an agency is like "money in the bank": it can always be drawn upon to support expensive developments, but only if it has been deposited in advance. Thus, even when an agency can support fewer big developments, it ought to continue a vigorous basic research effort in anticipation of the time when findings from basic research will assure the success of some future development.

Still, a part of the basic research budget will follow the budget for the mission-oriented agencies. The remainder, which I have identified with the National Science Foundation, would then go up or down as the Foundation's budget goes up or down. From the point of view of the scientist, such a way of arriving at our total expenditure for all basic science has the disadvantage that the bulk of science for its own sake is too visibly identified with a single agency—the National Science Foundation. But I think scientists will have to learn to live with some such situation. When we talk about large increases in science over the next 10 or so years, we are talking mainly about biology (which is broadly relevant to the mission of the National Institutes of Health) and about basic sciences in fields (like high-energy physics) which are not so clearly necessary, as is biology for the National Institutes of Health, to help the agencies succeed in their missions. The National Institutes of Health seems to me to be the Government agency, the achievement of whose mission is most directly and obviously dependent on a great push in our understanding of an underlying basic science, and whose mission will continue to enjoy greatly expanding public support. Hence I see no reason for concern about the future of the basic biological sciences: they will surely prosper as the fortunes of the National Institutes of Health prosper.

On the other hand, the necessity of expanding basic physical science research in order to further the missions of the other major agencies using science—mainly the Atomic Energy Commission, the Department of Defense, and the National Aeronautics and Space Administration—is not so obvious to me; nor can I visualize the budgets of these other agencies expanding as fast as that of the National Institutes of Health. Even with the best intentions on the part of these agencies to maintain support of their basic research, basic research in the physical sciences is faced with a crisis. Most of its support has come from the mission-oriented agencies, but these agencies will probably not expand their support of basic research as fast as our capacity to do basic research expands. We shall therefore be faced with two alternatives: either halt our expansion of basic physical research or find a source of support for it outside the mission-oriented agencies. I favor a continued, orderly expansion in the basic physical sciences; I therefore also favor the action that, above all, will make this expansion possible: namely, an accelerated expansion of the National Science Foundation. I would expect that the Foundation will have to become a billion-dollar-a-year agency by, say, 1970 if our country's preeminent position in the physical sciences is to be maintained. I can think of no political question concerning science more urgent than the question of expansion of the National Science Foundation.

References

(*1*) Many of my views have been influenced heavily by S. Toulmin's admirable paper, "The Complexity of Scientific Choice: A Stocktaking," *Minerva II*, pp. 343–359 (spring 1964).

(*2*) *Minerva I*, pp. 159–171 (winter 1963).

EXECUTIVE OFFICE OF THE PRESIDENT
BUREAU OF THE BUDGET
WASHINGTON, D. C.

Address of William D. Carey
Executive Assistant Director of the Bureau of the Budget
before the
Seventeenth National Conference of the
Administration of Research
Stanley Hotel
Estes Park, Colorado
September 11, 1963

RESEARCH, DEVELOPMENT, AND THE FEDERAL BUDGET

I take for my opening text the observation by Malcolm Muggeridge that human beings suffer more as a result of being unduly serious than of being unduly flippant; their worst blunders arise out of their solemnity, not out of their mirth.

The relationship of government to science in the postwar years is a case in point. Without very much visible deliberation, but with much solemnity, we have in little more than a decade elevated science to a role of extraordinary influence in national policy; and now that it is there, we are not very certain what to do with it. We have evolved a variety of rationalizations for what we have done and for what we doubtless will continue to do: science for national security, science for a better life, science for a growing economy, and science as a cultural end in itself. What we have done less well is to employ research support as an effective agent in upgrading higher education not just for a few leading institutions but at its broad base, provide safeguards against expediency in influencing career and vocational commitments, and establish a truly competitive market place within which science and technology must justify itself and its costs in fair competition with other social priorities and preferences.

We have gone through a whole generation of science administrators and political executives who developed ulcers in bringing science and technology to its present dimensions. Now we are inducing ulcers in another generation of scientists, administrators, economists, and politicians who are trying to solve the problems left by their predecessors. Is big science and technology for space and defense in fact bleeding the private economy of the incentive and capability for innovation and creativity? Where is the high-grade intellectual manpower coming from to make good the commitments we are so freely entering into for the next decade? How are we to make certain that rising expenditures for research and development are not lost by dwindling productivity and quality in research? Can some way be found to ensure an adequate spinoff from space and defense research for the benefit of civilian technology? Have we approached the time for a healthy shakingdown of our Federal science and technology for purposes of taking stock and consolidating our efforts where the priorities lie?

In short, reaction is at last setting in. It is apparent in the scientific community, perhaps because of fears lest major programs and enormous hardware costs will push less exotic science to one side. It is apparent also in the Executive Branch of the Federal Government, where the budgetary pinch is becoming acute. And it is perhaps most spectacularly apparent in the Congress, where a mounting wail of frustration and uneasiness is being reflected in a rash of proposals to bring science and technology to heel, possibly reflecting a thought uttered by the quotable Mr. Justice Holmes, who said "We need education in the obvious more than investigation of the obscure."

The point I want to make is that Government's part in the research and development business has now reached the point where it commands attention because of its sheer size and propensity for growth. From here on, we will have to be more choosy in what we do, and better prepared to supply answers to questions about marginal costs and benefits. The budget this year for research and development is a husky $15 billion. Its growth potential dwarfs anything else in the budget. Someone has figured out that the doubling time for R & D as a fraction of national income in only seven years, and that if this continued for 30 years research and development would rise to one-half of the national income. Dr. James Killian estimates that on the basis of present trends, total national expenditures for research and development could exceed $40 billion by 1970, with the Federal Government tagged for most of it.

In my judgment, without for a moment discounting the talent of the R & D community for finding new and expensive frontiers, these trends are not realistic. In absolute terms, I expect the level of Federal support for R & D to rise, but at a diminishing rate which could produce a levelling-off of the budget for science and technology over the next few years. Nevertheless, even a moderate upward trend is not to be taken for granted. Funds for R & D have come so easily during the past decade that in some quarters of the scientific community we find a state of mind that assumes that the miracle of the loaves and the fishes will go on indefinitely, and that the mere assertion of a valid scientific need will suffice to turn on the financial gusher once more. I should like to make it plain that the justification for the sixteenth and seventeenth billion will have to be very different from the justification which sufficed for the first billion. We have arrived at the point in the Government's budget where the trends of the past are meaningless. A budget which quadrupled in the Forties and doubled again in the Fifties is extremely unlikely to behave in that style in the Sixties, even for science and technology. And so that next billion dollars will come under both executive and legislative scrutiny of a kind previously unknown. And the scientific community will have to take a major responsibility for being sure that Government chooses to put its dollars behind the best of many choices.

I would further hazard the view that this tightening of the Federal pursestrings will cause some convulsions in the scientific community. When dollars for Big Science become scarcer, the science community can be expected to break ranks and form clusters of opinion and dissent to a greater extent than is the case to date. If a massive program for high energy nuclear physics costing six to eight billion dollars, or a development program for a supersonic commercial air transport costing even one billion dollars, has the effect of heralding the displacement of other urgent claims for Federal support, we can expect the fur to fly and the issues to be illuminated with far more pungency than we have seen thus far. And this is precisely as it ought to be. This is the competitive market place at last.

To be sure, with this comes a new hazard, and one which is already visible. This is the danger of injecting the technique of the "pork barrel" into the area of science and technology. While I run some risk of excommunication for even bringing the matter up, it is a risk someone needs to take. We are talking about large sums of money, highly attactive physical plant, research tools to tantalize any self-respecting scientist with a forgivable eye on a Nobel Prize. We are speaking of national prestige science and technology which can be vital to the intellectual standing of a university or a group of universities. Where the tools are located, where the facilities are built, how funds are disbursed to equalize research opportunity among the various sections of the country--all these are very real issues in the era of Big Science. Scientists and educators with all this at stake are already learning how to bring pressure on their political representatives on their behalf, first for the approval of the programs and then for the location of facilities and the disbursing of operating funds. As new thresholds of research and experimentation materialize requiring highly sophisticated hardware, this phenomenon will become a force to be reckoned with. If I may say so, we can expect to face this not only in the area of applied science and technology, but even within that cloistered and rarefied world concerned with basic research. But if I am right about all this, and I think I am, one result will be to make science somewhat less luminous and other-worldly than it has been to date, and add a slight tinge of green to its halo.

As a more or less living example of the type of people who work on the Federal budget, I should like to venture some general observations about that operation in so far as it touches science and technology.

To begin with, the budgetary process is the closest thing we have in Government to a systematic effort at resource planning. Imperfect as it is, we would probably have to invent it if it did not already exist. What it provides is a round-the-year examination and re-examination of needs and resources in a changing society, in a setting of economic purposefulness and a Presidential program of political action. It is a process which stresses challenge and the evaluation of responses to that challenge. It reaches for rational criteria against which to sift competing claims and demands, and it aims toward a workable synthesis of goals within a financial and economic plan. In our framework of government, the budget process is the President's chief tool for facing up to the issue of what must be done now and what must wait. Underlying the exercise of this process there must, of course, be some basic strategy, and this will vary with Presidents and their public philosophies. One President may view the budget as a built-in Maginot Line against further extension of the arc of public action and intervention, while another will recognize it as an opportunity to advance our society purposefully in many fields of action important to both internal and external progress.

The Bureau of the Budget has never agreed with suggestions that it should establish within its structure a Division of Science, staffed with qualified scientists and engineers, to review R & D proposals. We prefer to do our work by using a broad approach which examines program issues in the field of science and technology from the standpoints of public policy, soundness of justification, and the availability of money and manpower, and the balance of financial effort as among alternative program commitments. To be sure, our analysis frequently requires inputs of sophisticated professional judgment as to technical feasibility, state of the art, and possible alternatives to a proposed line of development, as for example in the moon program or in the missile field. In recent years, however, we have been able to obtain this kind of judgment through the Office of Science and Technology and the President's Science Advisory Committee. We have also arranged each year to undertake an overview of selected fields of science with the objective of relating levels of effort and support in particularly vital areas of science and technology to our general budgetary planning. This year, for example, we selected the areas of atmospheric science, oceanography, water research, high energy nuclear physics, basic science, and sciency information for special review, and we conducted this exercise jointly with the office of the President's Science Advisor. I might say that the budget review process is not slanted toward exposing the weaknesses and follies of science proposals, although at times it has that result. But the process we employ is also calculated to bring out situations where we feel that there are distortions and imbalances in the Government's support of science and technology and education, and in such instances we look for corrective solutions even though this might actually run the totals up.

I would like to be able to assure this select company that the budget process employs an ideal combination of criteria which guarantees a fully rational exercise in decision-making where we are dealing with science and technology. The truth is that we have a long way to travel before achieving that Utopia. There are still too many variables, too many unknowns, to leave us comfortable. We have no way to measure satisfactorily the potential yield to civilian technology from military and space R & D. We lack dependable data to judge whether we are approaching --or have already reached--the point where Government-supported science and technology is displacing or impeding private investment in the R & D which feeds economic growth and creates the new products and markets needed for an economy on the path to full employment. Our crystal ball is still very foggy in forecasting what all this scientific and technical exuberance may mean in accelerating automation with all its implications on the mix of skills and utilization of our basic labor force. After twelve years of the National Science Foundation, we are as far away as ever from any clue as to how much basic research should be supported, year in and year out, as a national purpose, and we continue in that area to depend too much on the oversimplified formula of budgeting for some rough percentage of the worthwhile acceptable research proposals that are expected to roll in. We have found no absolute answers to the dilemma of priorities when we are faced with a well-reasoned but vastly expensive long range program in high energy nuclear physics and simultaneously programs for major outlays for oceanography, supersonic aircraft development, and the moon program; how does one assign relative values to the spectrum of the opportunities to advance knowledge? James Reston of the New York Times has seen fit to draw attention to the dilemma of priorities in a piece entitled "Kennedy and the Scientists: the Quiet War." It is not a war at all, but an abundance of opportunities which Government itself has invited and which only Government can seize for the benefit of its people. The problem is that Government today cannot take the easy way of recognizing them all and endowing science and technology with an unlimited drawing account. As I said earlier, the sixteenth and seventeenth billion are harder to come by than the first. Our problem is an embarrassment of intellectual riches which is not matched by the affluence to employ them full. While Mr. Reston is entitled to his doubts about the adequacy of the Government's method for reaching sound choices, it is my view that the difficulty here is not one of inventing more super-authorities but rather one of organizing "research about research," of developing more adequate insights into cost-benefit relationships, of illuminating our value analysis so that we can with greater confidence strike a balance between being "first" in high energy accelerators and being first in education and in decent living and job opportunity. I do not think that Government alone can reach these answers, but perhaps Government can--and indeed I believe it must--be as proportionately lavish in stimulating this kind of intellectual inquiry as it has been in endowing science and technology.

Perhaps, after all, Mr. Justice Holmes had the right perspective. He observed, half a century ago:

"If I am right, it will be a slow business for out people to reach rational views, assuming that we are allowed to work peaceably to that end. But as I grow older I grow calm. If I feel what are perhaps an old man's apprehensions, that competition from new races will cut deeper than working men's disputes and will test whether we can hand together and fight; if I feel that we are running through the world's resources at a pace that we cannot keep, I do not lose my hopes. I do not pin in dreams for the future to my country or even to my race. I think it probable that civilization somehow will last as long as I care to look ahead--perhaps with smaller numbers, but perhaps also bred to greatness and splendor by science. I think it not improbable that man, like the grub that prepares a chamber for the winged thing it never has seen but is to be--that man may have cosmic destinies that he does not understand. And so beyond the vision of battling races and an impoverished earth, I catch a dreaming glimps of peace."

A PROPOSAL FOR A YEARLY PRESIDENTIAL REPORT ON SCIENCE

A Strategy Document for the Public Enlightenment

By WILLIAM D. CAREY

IF I were obliged to make a list of the most urgent problems facing the Congress of the United States in the field of its organization and functions, I doubt very much that I would rank science at the head of the list. So much for perspective.

I think we have been more critical of the behavior of Congress in dealing with science than the facts justify. Where the major commitments of the government are concerned—atomic energy, extraterrestrial space, defense, and medical research—by my standards the Congress has acquitted itself well. It is chiefly, I believe, in the less articulate sectors of the research program that some stresses and dissatisfactions have cropped up. Beyond this, we have observed in some quarters a growing passion to focus "science policy"—vaguely defined—in the higher reaches of legislative structure.

It must be said, sadly enough, that the scientific community itself has not always shown enthusiasm for improving Congressional understanding of the research business. This was brought home to me a couple of years ago when I spoke before a large assemblage of research scientists and administrators. I appeared coincidentally with the first stirrings of the crisis of congressional confidence in the growth and coordination of research. And I remember clearly that one individual after another rose to voice dismay at the prospect of the Congress injecting itself into inquiries into these matters. How can we prevent this from happening? What can be done to head it off? How can we keep research out of politics?

To me this signified a state of mind that regarded research and development as untouchable, to be screened at all costs from legislative caprice. Research was doing nicely under the wing of the Executive, and only trouble could result by tempting Congress to upset the equilibrium. It did not seem to occur to them that Congressional oversight could manifest itself in a constructive form.

I think that much of this mentality has now subsided in the wake of the work of the special committees of inquiry, which took high ground. There have been no scandals, no public executions, and few indictments. There will always be the risk that a member of Congress will show exasperation with the moon program or research into the mating habits of frogs, and that someone may twist an arm or two to influence the location of a plush research facility. But these risks are within the parameters of normalcy.

Still, I take the view that such tensions as have existed between the research brotherhood and the Congress cannot all be blamed on the latter. Some of the cohorts of science appear to have wanted all the prerogatives of a state religion without any of the embarrassments. This, too, I trust, has waned.

In addressing the question of how to equip the Congress to deal effectively with science, I am not bemused with the thought that it is necessary to foist a spate of new committees or institutional innovations on an already overloaded and overstructured legislative body. By my lights, the place to start is at the other end of town.

If the Congress feels starved for facts, if it is baffled at finding science behind every bureaucratic rock, if it fails to see intrinsic merit in the more arcane nooks of basic science, if it hunts vainly for signs of a broad strategy for science, if it cannot identify priorities for scientific choice, we have ourselves to blame. We are simply not providing the answers. And if we are not providing them because we do not have them, then we need to ask whether we are doing enough to get them. In my judgment, Congress is not anxious to take over the policy initiative for scientific research. It merely takes the quaint view that *somebody* should seize the initiative and do it well and thoroughly.

I have long preached, unsuccessfully, for the issuance once each year of a report from the Executive Office of the President on the substance, organization, costs, goals, problems, and progress of science and technology. I have thought of this as a strategy document similar to the Economic Report. A report such as this ought to tell us in highlight form where we have been in science, where we are now, where we want to go, why, and with what rate of investment. It should deal with the roles of both the private and government sectors of support and performance, and it should be qualitative as well as informational. I would be first to grant that a report like this would not solve the entire problem, but I have the feeling that it could supply in great part the element that is now so conspicuously missing—a *framework* for considering the state of science and technology in the larger economy of our public policy.

I should like to see such a report treated by Congress in much the same manner as the Economic Report is treated, with public hearings and testimony from invited outside parties. My preference would be for joint hearings

THE TIMELINESS OF WILLIAM D. CAREY'S PROPOSAL for an annual summation of the state of American science by the Executive Office of the President of the United States hardly needs comment. One of the most fanciful politico-scientific circuses ever staged with taxpayers' money is now underway. One hundred and ten cities across the land are bidding competitively for the opportunity to build within their precincts the world's biggest atom-smasher at a cost somewhere in the neighborhood of $300 million. In order to enter the competition, each town had to officially claim to possess—or be prepared to obtain virtually instantaneously—a sufficiently broad and soundly footed sweep of bedrock to hold the gigantic instrument, generous quantities of underground water to cool the operation, and a brilliant galaxy of brains capable of designing experiments which alone will make the installation worthwhile. Sooner or later, the people will have to be told the fantastic truth. What better source for such news than the White House?

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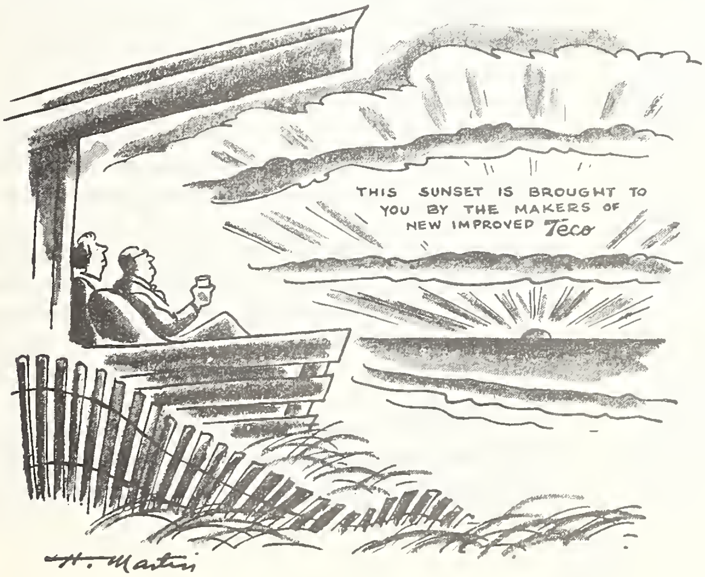
by the House and Senate, possibly by a Joint Committee whose functions would be limited to examining the report and conducting the hearings, and which would draw staff support from the science policy division of the Legislative Reference Service. I believe—possibly all by myself—that the very requirement for such a comprehensive annual statement would itself force action from both the Executive and the various committees in both Houses of Congress, that it would serve to point up the right issues and improve accountability to do something about them.

Another innovation that would have a certain merit also begins with the executive branch. It relates to budgeting for research and development. I think it would be entirely practicable if the Budget Bureau were to approach the chairmen of the Appropriations Committees to suggest that each year there be a comprehensive presentation by the Bureau and the Office of Science and Technology on the R&D [research and development] component of the new budget. Such a confrontation should come immediately after the Budget Director and the Secretary of the Treasury have completed their normal annual presentation and defense of the President's Budget. It is my thought that such a briefing and question-and-answer session might go some distance to make the science budget less baffling than it is, and tie together in understandable terms the fragments of R&D which are scattered all through the budget with resulting irritation to the budget subcommittees. The proposal is modest, poaches on no committee preserves, introduces no super-committees, and could be accommodated with no great strain on anybody concerned.

The question which has repeatedly arisen in Congress is "Who, if anybody, is in charge of coordinating R&D?" What Congress wants more than anything else is evidence that the Executive is running a tight ship and knows what it is doing. Congress in its present incarnation is perfectly capable of making up its mind about the moon program, medical research, and the Mohole. But it is less prepared to certify that twelve or fifteen agencies have their meteorology programs in balance, or that feedback from supported research is being put to good use. Congress cannot make sense out of the decision-making procedure of the agencies in deciding how—if at all—research priorities are defined and resources matched up with them. And in this the Congress has company. If we in the Budget Bureau were pressed, we would have to answer in too many cases that we don't know *how* we do it, but we do it all the same.


THIS SUNSET IS BROUGHT TO YOU BY THE MAKERS OF NEW IMPROVED Teco
H. Martin

The present stabilization of the research and development budget gives us a breathing spell which ought not to be wasted. I suspect that before long the expenditure curve will resume its upward movement. Then questions will again be asked. Meantime, we ought to decide what we want to do about grants versus contracts, university cost participation in research, indirect expense allowances, inconsistencies in administrative controls, in-house versus contract research, the future of the national laboratories, and overconcentration of university research. We should also face up to the untouched issues of criteria in scientific choice, and the irrational lack of balance in our support or nonsupport of technological innovation.

THE "hairshirt" function is critical to representative government, and one doesn't find it in the executive arm. What we need, and do not have sufficiently, is some way for issues of science policy and priority to be sharpened and argued—in other words, we need a marketplace where the competition can make itself conspicuous. There is plenty of potential dissent within the scientific community; it deserves an outlet. This is one more reason why I suggest so strongly that Congress should require of the Executive a periodic accounting and an airing of its performance and its expectations, in the full light of constructive criticism.

If we have made mistakes in handling science, they were the price we paid for rapid expansion. Congress and the Executive are probably equally responsible. I think the costs have been well inside the range of acceptability. And we have learned something. We have unleashed a force in society that is here to stay, and that contains an extraordinary creative potential . . . a potential that will not express itself as a unity, but in diversity—as a function of business investment, communications technology, transportation technology, molecular biology. I do not find it illogical that our government machinery should reflect a parallel diversity, mellowed by perspective.

William D. Carey is Executive Assistant Director of the U.S. Budget Bureau. The text above reflects remarks originally made at a Brookings Institution seminar on science, technology, and public policy.

The Science of Science

Can we use scientific methods to analyze the structure of science itself? With the article by Derek J. de Solla Price that follows, the Bulletin *presents the second of six articles based upon the "Monday Lectures," a series of talks given at the University of Chicago in the spring of 1965 in the hope of initiating anew discussion on the nature of man, his place in the universe, and his biological, intellectual, and social potentialities. Dr. Price is professor of the history of science at Yale University and author of* Science Since Babylon *and* Big Science, Little Science. *The complete texts of the Monday Lectures are being published by the University of Chicago Press, under the title* New Views of the Nature of Man.

A heaven for historians would be a place of broken idols—where evidence is at hand to prove every popular story false. Paul Revere did not ride at midnight, Washington had no cherry tree, and the stories of the Bible are all necessarily false.

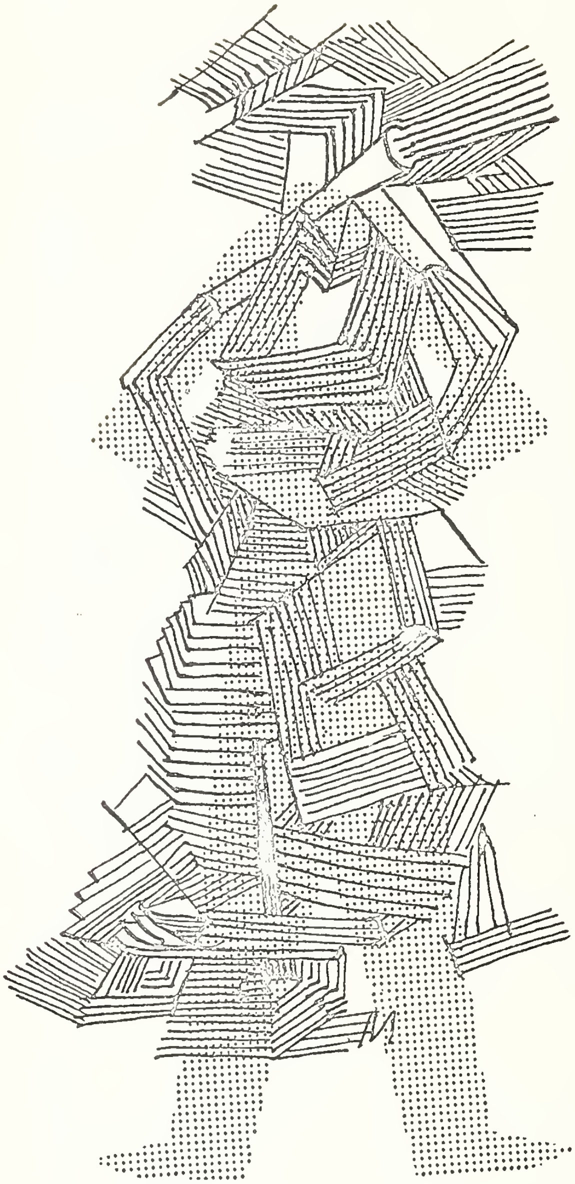
The historian's special motivation is largely the desire to dig deeper and find out why and how things really happened. In the course of this digging they always hope to find a new revealed truth, in which the real reason is vastly different from the popular or naive notions of our school days.

My professional odyssey from physicist to historian of science taught me that research in both subjects felt much the same from inside. The desire of the physicist to achieve some great new understanding of the universe matches that of the historian to comprehend the workings of our society—and both have the iconoclastic lust. The history of science has a particularly high incidence of fragile idols, of stories illustrating a conventional wisdom about science: a wisdom soon found to be but a veneer of wise varnish over a base of superstition and half-truth.

As a physicist I was aware of the objectivity of scientists, the relation between experiment and theory, the role of mathematics in physical theory, and the relation between pure science and applied technology. I became aware that in most of these things I had only partial knowledge. For example, Copernicus did not have a more accurate and economical planetary theory than his predecessors but one which, though partially true, should have been (and was) unacceptable at the time to any good scientist. Galileo almost certainly did not make an experiment from the Tower of Pisa; as a nonmathematical mechanician and popular expositor of physical principles, he did not need to.

More idols break when one looks at biographies of scientists and at their priority disputes. Far from traditional objectivity and impersonality, the genesis of ideas comes from highly subjective elements in each man, and acceptance or rejection is often surrounded by issues of personality. More gods topple when one looks at the history of technology and sees it so different from that of the history of science. It becomes clear that technology is not anything so simple as the application of new scientific knowledge to the mastery of nature and the good of nations.

The inevitable conclusion is that our knowledge of modern science may be just as much beset by naiveté and misunderstanding, half-truth and whole error, as our



DEREK J. DE SOLLA PRICE

knowledge of past science. Indeed, there has recently been a remarkable reinforcement of such suspicions by the cross-fertilization of the history of science with new findings from sociology and psychology, and from the growth of radical ideas (such as those of Kuhn and Agassiz) in the historiography of science. These contribute to an inner theory that takes the empirical generalizations of historians about the past and raises them to a new level where we can see that—unless radical changes occur—things necessarily happen as they do, in the present and future as well as in the past.

It is particularly intriguing that science seems in many ways universal, supranational, and suprasocietal; its behavior appears determined by its inherent nature much more than by the properties of the ambient society or the aspirations of the men who are its agents or patrons. This is not, of course, entirely so, but enough so that the history of science attains universal currency and mechanistic determination that can be profoundly disturbing to the conventional historian acclimated to the fate of a civilization depending on the length of Cleopatra's nose or the private aspirations of Napoleon.

From this background I must approach modern science with a mixture of doubt and hope. The doubts are about the accuracy of our knowledge of the way science behaves, develops, and interacts with society. Yet I have hope that one can effectively pursue hard knowledge in this area—knowledge that might have an attractive and provoking universal validity.

• *THE MYSTIQUE*

The new knowledge about science seems to be growing amid strong resistance from within and without, in a world that demands much more consumption than supply. Resistance from outside is traditional. It has always been part of the special mystique of the scientist that he alone can really know about science. An outsider must be presumed ignorant, not merely of the technical facts, but also of that special knowledge of the life of science won only on its battlefields. Competent art critics, however, may never have painted, and there are music critics who cannot play an instrument but who wield a pen that contributes much to their creative industry. Similarly, legions of teachers of English communicate appreciation and criticism of literature primarily because it is part of our culture, not because such teaching shall also produce novelists, poets, and essayists.

Better still as an example is the now accepted scholarship of economics. One does not demand of a professor of economics that he be first a good and successful businessman, or even claim that a grounding in economics will make a better businessman. But economics is regarded as an aspect of our society that is a fit and proper subject of scholarly curiosity; also, such scholarship may be quite important in deciding fiscal policy and preventing the economic evils of the bad old days when we had only the advice of good businessmen. In science there has been no analogue of this subject heretofore. Perhaps science has a far deeper mystique than business. Every man has some sort of economic life, but without professional qualification in science one is automatically debarred from knowledge except through diluted popularizations and also through the impact of technology on daily life.

There is then a traditional resistance by scientists to any discussion of science from outsiders. Even in such fields as the history of science and its sociology there is another sort of resistance. Most of my colleagues have such purposes as understanding ancient scientific texts or uncovering the circumstances in which quantum mechanics had its genesis. We have been far too busy winning basic facts and understanding to feel justified in setting ourselves up as critics and analysts of modern science.

• *BACKDROP FOR ANALYSIS*

In spite of internal and external resistance, or perhaps because of it, there has been growing steadily the sort of criticism and analysis that I have characterized as an analogue of economics. Some such scholarship is quite ancient, but the first big push of the recent development came in the late twenties and early thirties. This came about largely through the scientists roused to a new level of political consciousness by the development of the Soviet Union. In that country, communism meant socialism plus a nascent science-based educational system and technology-based economy. Science and technology graduated from a condiment to a vitamin in the diet of society.

The famous "planning of science" debates arose, and the equally famous "freedom in science" opposition. Although the discussions were sharply divided by left and right, protagonists on both sides dug deep into what little then existed of the history—as well as the sociology, psychology, and economics—of science, to provide ammunition for their big guns. It was at this time that the term "science of science" was first coined.

The battle was quieted at its height by the greater forces of World War II. Science and technology erupted into public consciousness through their military role. A scientist did not need political motivation to be conscious of the social relations of science. As Oppenheimer said, the physicist had come to know original sin. By the end of the war this country had a huge supply of active scientific manpower that had to return to civilian work in a land that now set a high value upon such competence but had few facilities for it outside the universities.

• *THE POSTWAR PUSH*

In the postwar years, all arguments of planning and freedom notwithstanding, the government had to make funds available for science in the universities and elsewhere. Both the government and the scientists were interested in insuring that science be promoted for the good of society and the nation. The tide ran high and soon Washington—and Moscow—began to fill with administrators and experts whose task was building and maintaining this effort.

Two important things have happened in the twenty years ensuing. First, science has become a productive force in society. It had already graduated from condiment to vitamin; now it has become our very meat and potatoes. Second, the twenty years have brought a new expertise to the administration and nourishment of science and technology for social goals. Many processes of decisionmaking have still to be played by ear; but in half a generation there seems also to have begun all over the world some formulation and consolidation of a conventional wisdom about ways in which science policy can—and cannot—operate.

Slowly there has been developing a corpus of expert knowledge about the organization and behavior of science, which now has to be learned the hard way by anyone coming into the business. And this is beginning to make it tough for the eminent scientist who is kicked upstairs to a high administrative post.

• *THE NEW DISCIPLINE.*

Attending this accumulation of expertise there has begun a most exciting new development: the first few steps have been taken to relate this body of knowledge with those disinterested areas of scholarship where science and scientists have been studied from the viewpoints of historians, sociologists, psychologists, and economists. I feel we shall have here a rich cross-fertilization among the several fields of scholarship, and between each of them and the relevant areas of expert organizational knowledge. They are gradually beginning to come out of their original isolation and to nourish each other so as ultimately to produce a single discipline. Some of us still cavil at this embryonic "science of science," and hope it will not be as phony as it sounds at first. It may be a long time before it is welded together instead of being the several splinters and ad hoc investigations which it is now.

The present science of science consists of a stratum of knowledge being explored in two directions. From the top, administrators and experts on science policy are forever examining new areas and digging deeper for a suitable base for their findings. From the bottom, those who start with historical analyses and sociological and psychological characteristics of scientists are gradually building a picture of how science and scientists work. Somewhere in between are the economists and statisticians who reach out to theoretical bases below and stock-in-trade for the administrator above.

The needs for the science of science are becoming greater as old problems magnify and new crises explode. The increasing importance of science in society is matched only by the rate at which its costs grow and the extent to which it dominates the lives of more people in more and more countries. We must therefore force the development of this new discipline and bring it to bear on present needs.

• A COMPENDIUM

It is in the spirit of intense curiosity and urgent need that I shall now attempt a task never hitherto expressly formulated: to provide a compendium of research achieved, in progress, and yet to be attempted, which would draw together most of what we know about science and make it available as a foundation for decision-making. Any such program must be biased by my own interests and limited by my ignorance of much that is already available. I can only hope that the provocation may lead more people into this important underdeveloped area.

The initial problems are inevitably those of methodology and concepts. For the methodology, we should choose as a matrix a quantitative approach. This is because we have already available a large corpus of numerical information about manpower, money, publications, and institutions, bearing directly on many interesting and important current issues. Further, many administrative situations call for quantitative decisions—for example, allocating resources to several competing claimants—rather than yes or no responses. Lastly, one can often proceed from a quantitative treatment or model to a qualitative one, but only with great difficulty can one do the opposite. Thus we must begin with a numerical analysis and draw from that a set of models and theories to link with the qualitative portions of our treatment.

If the methodology is quantitative, the conceptual models and definitions must be chosen with that in mind. Our first choice will entail many others and set the pattern of the matrix through compatibility—each part must fit with every other. The quantitative starting point is therefore important; it must delimit the universe to be considered. We must find a quantifying definition for science as distinct from non-science.

• AN OPERATIONAL DEFINITION

To begin with then, I shall use an operational definition of science that can act as a peg for a good deal of the work of sociologists and historians, and about which a good store of quantitative information is readily available. All historians must take as their point of departure the prime documents in the case—for historians of science this means scientific papers in learned journals and the books in which science is published. The scientific publication represents in a sense an end-product and a fixed point in the discussions. To the scientist himself it represents a mysteriously powerful, eternal open archive into which he reads his findings.

Pathological cases exist such as that of Henry Cavendish who researched diligently, but did not publish the bulk of his findings. But is such unpublished work, or that suppressed as a national secret, a contribution to science? In general, it is fair enough to say it is not, although it is a little hard to loose Cavendish from the ranks of contributing scientists, or to admit no contribution from the unpublished researches of Leonardo da Vinci. A more serious consequence is that this usage distinguishes science from a great deal of technology in which the end-product may involve no publications (or only secret ones), but rather a new product or process or a portion of one which might not even be recorded separately in a patent.

Our definition stands then: science is that which is published in scientific journals, papers, reports, and books. In short, it is that which is embodied in the literature. This literature is far easier to define, delimit, and count than anything else one might deal with. Because of its central function for scientists it has been subjected to centuries of systematization by indexes, classifications, journals of abstracts, and retrieval systems. By far the greater part of the literature is now or has been on the research front. (We might distinguish this as research literature.) A lesser part consists of summaries, surveys, textbooks, and popular treatises. All such literature can be, and in very many cases has been, counted, classified, and followed through the years. For example, the chief component of research literature can be defined as that included in papers published in scientific serials such as those given in the *World List of Scientific Periodicals*—familiar to all reference librarians.

• *QUANTITATIVE RESULTS*

With such a first step, quantitative results begin to emerge. We know that the number of journals concerned has been growing steadily at a rate of five per cent per year since the effective beginning around 1700; this gives a doubling every fifteen years, a factor of ten every fifty years, and a factor of about 100,000 since 1700. We know too that journals have a very high mortality; for every three born, only one now survives, and the current worldwide list is therefore only about 35,000. Let us suppose that all bound annual volumes of all periodicals were the same size. The whole library would then contain 100,000 titles, ranging from a single volume to more than 250 for the oldest. Half of this library would be contained in about 300 journals, each of which had a run greater than about fifteen years. But for this year's new additions one would have 35,000 volumes, each for a different journal. The high mortality therefore gives rise to a small core of long-lived journals that carry a high proportion of the literature. Outside this core is an almost open-ended community of journals, important in any one year, but contributing less and less to the total archive.

To get this result we have made the unwarranted assumption that all annual volumes of periodicals are the same size. In fact, they are not. It happens that there is a good correlation between the ages of the journals and their sizes, and probably their prestige and importance. Thus, in general, the oldest journals are also the biggest and the most important; hence the core will contain much more than half the literature in numbers of papers and even more than this if we weigh it by any reasonable measure of worthiness. To jump ahead a little, the core phenomenon is such that if one starts from the very tiny group of journals, papers, projects, or men that account for something more than half the total effort, and proceed outward into the almost infinite general population, one gets only a small—perhaps ten per cent—increase in value for each doubling of the population considered. This is why total lists of journals or scientists are so huge while the periodicals and people that really matter are quite few.

• *THE SCIENCE CITATION INDEX*

The difficulty, so far, is that statistical treatment has depended on an arbitrary selection of journals. This can be converted to an objective method that tells much more. We have just beginning to be available, a device: the *Science Citation Index*. This takes about 1,000 of the most important scientific journals of the world, and lists by author every paper in them as well as all the sources cited by each of the original papers. The index will show what material there is following a paper published last year; since it will list whatever new papers cite the previous work. Thus there is a bibliographic tool that can go forward in time, rather than only backward as in old-style bibliography hunting.

It is possible to use this index statistically. Even though much citation is purely decorative, statistical behavior in the large is regular and meaningful. One can, for example, start from each journal and tabulate the others it cites and those that cite it; these lists may then be ranked, or a total matrix established showing how each journal fits with its neighbors. Note that this is largely independent of the original choice of journals to index. Even if, say, *Physical Review* had been omitted from the sources, after a few other journals publishing physics papers had been analyzed it would appear that *Physical Review* was a most important sector of citations. Taking into account the numbers of papers available in each journal to provide citations, and the number available to be cited, it still appears that some journals clump together in a mutually citing population, whereas other journals and clumps are far from the collection being considered. These clumps, each consisting of a central core surrounded by a diffuse body of lesser literature, correspond roughly to the separate disciplines of science. In principle, I believe, they could be mapped, with hybrid subjects like physical chemistry and chemical physics occupying the borderlands.

• *FOLLOWING THE PATTERN*

Not only could such a map be drawn quite objectively, but one could also follow its changing pattern to show activity bursting out here, dying there, as fields come into being, increase or decrease their production of papers, or die completely. As a result, I think one would find that a large class of allegedly scientific journals do not cite other journals much, and are not much cited. To such a genus belongs much of the literature of engineering, clinical medicine, or data reporting; this non-cumulating literature seems to be some epiphenomenon of science, if it be science at all.

In any case, one has now in principle a way of deciding objectively what literature there is in the cumulation of science, and how it is divided by scientific sectors and grows at various rates. By sampling, one can determine statistically how this breaks down by countries of publication, languages, etc. We even have some trial investigations that show, for the United States in particular, the source of funds supporting research and the way this changed in the critical period when federal funds were beginning to replace private and university support. As it happens, it did not alter the growth rate of publication in the fields considered.

• *SCIENCE AND SIZE*

If we examine the breakdowns by country and by field it would appear that most countries have amounts of the various sciences in proportion to the sizes of the fields and their own national scientific size. What is going on if there are significant deviations from this total picture? Suppose physics on the world scale is fifteen per cent of the total scientific effort, but in the United States it is thirty per cent. I think there would be a good case for calling this wrong and uneconomic policy unless some positive reason could be adduced to the contrary. Physics research is universal, and an over-contribution by one country would be adding more to the world total than it would receive. The money and support would be better utilized in adding to the relatively neglected sciences in proportion to their sizes on the world market. Thus, in principle, policies for support of basic sciences may be objectively handled, and fundings suitably proportioned for those cases where one does not wish wilfully to disturb an evident status quo.

• *QUANTIFYING THE MANPOWER*

Having established an objective monitoring of the literature, one may now proceed to problems of scientific manpower. For ease in quantification, we shall consider a person to be a scientist if at any time in his life he has authored (or perhaps even co-authored) a paper in one of the scientific journals that we have already defined and classified in principle. Again, in principle, there is little difficulty in showing a mortality pattern in productivity which is relatively constant from country to country, from field to field, and even rather spectacularly constant over two or three centuries.

The natural distribution of productivity, and perhaps even degrees of goodness and competence, follow again something like the log-normal curve that one would expect if scientific talent were distributed through the population like height, wealth, or anything else. The high mortality, already found in journals, tells us that for every three people once on the research front, about two have been excreted from it, presumably into fields that do not cumulate literature or into nonscientific activities. In principle, if we know the volume of literature in any field and country and time, we can compute the number of minimal scientists so defined and also the number of any higher degree of productivity. In particular we can compute the number of core scientists responsible for half the volume and more than half the important work. We can also see the number that must be brought to the point of publishing a single paper, so as to maintain this population and enable it to grow at the rate prescribed by the world total.

• *EXPANDING THE STUDY*

Having described an objective scheme whereby scientific literature and manpower may be measured and related, one may proceed in several directions. First, the large number of existing non-ideal definitions and investigations can be related to this corpus, extending results in a very rich and practical way. Second, one can consider why the various statistical regularities found empirically have their particular form; in many cases we can even begin to see certain underlying laws and principles that have an obvious validity. Further, of course, the now well-integrated central corpus can be extended to link with historical and sociological studies as well as with ramification on lines important to science policy discussions.

Even though we have no overall map for the clumps of journals on a field-by-field basis, we have for several of the most important journals in various fields measurements of the incidence of the numbers of authors per paper and the number of references per paper. From these data it is quite clear that there is a field-by-field variation. A surprising aspect of multiple authorship is its remarkable growth in some areas long before the coming of big machines and the teams required to do experiments with them. From the results, one supposes that papers with twenty-seven authors might well be regarded as a means of communication between the people involved as well as of securing publications for otherwise minimal producers. Here, the big machine is perhaps more the occasion for multiplicity than its cause. Further, from the pattern of the amounts of citations, it would appear that some areas—notably technologies and clinical medicine—feed on previous literature vary much less than is usual, having only about five references per paper instead of the norm of fifteen. Is there a different convention in some subjects about how many papers to cite? I think not. It would appear, rather, that the function of the literature of these fields is not primarily to provide data for other workers. One arrives at the provocative result that although literature is produced it is by our definition apparently only weakly scientific.

• *THE LAWS OF MOTION*

Among the more important laws of motion in the science of science, I would like to consider that which tells us the nature of distributions in size, quality, etc., and that which governs the normal way in which things measured grow with time. The distribution laws giving the number of authors producing n papers or the number of institutions producing n scientists show the same pattern of extreme inequality that exists for the distribution of sizes of cities within a country or of personal incomes in a competitive society. The chance that a man will go from his first paper to his second (about one in four) is the same as the chance of going from the second to the fourth, the fourth to the eighth, etc. And the chance of an institution growing from ten PhDs in physics a year to twenty is the same as that from 100 to 200.

One gets, therefore, in a normal population a random curve of errors distributing not the measures but their logarithms. This simple model provides a rather good first approximation to the empirical observations: it is a built-in mechanism of science, and acts as a sort of cybernetic control over a population. It would be as difficult to enforce a decree establishing 1,000 equal institutions, each producing ten science PhDs a year, as it would be to enforce a decision that our huge cities be abolished and the population uniformly distributed over the country.

• INDEXING AND AUTHOR INTERACTIONS

Using the techniques of citation indexing, I have been attempting to see what happens if one looks for the relations, not between one scientific journal and another, but between individual authors. It appears that the entire science research front may be divided into distinct clumps of authors, each having some 100 members, and that within each clump the peer group is living by taking in each other's washing.

The properties of these small clumps are particularly exciting for the social analysis of science and may be of deep significance in practical problems of administering and serving the needs of such groups. Even more important, we can begin to see that it is this mechanism for rapid accumulation of research through the interaction of a peer group which distinguishes the progress of science from that of scholarship in general. In fact it is possible to derive a parameter which measures research growth in a field by drawing on immediately previous work rather than on the entire past of derived results. This parameter then gives a measure of the place of that field in the research spectrum—from pure science to pure non-science. Further, it is this short-range interaction that makes science grow so much faster than non-science. In fact, the old knowledge must breed now at constant rate so that one has growth at compound interest—a linear growth of the logarithm. It is a necessary consequence of the basic situation, rather than a mere empirical finding.

Lastly I turn to some samples of how this new theory may be utilized for practical planning. The first deals with the whole area of economic studies of science. Our new technique gives us a means of estimating, field by field, country by country, the number of people engaged at any time in producing the cumulating end-product of literature which constitutes the stuff of scientific knowledge. It can also tell us the effectiveness with which the cumulation is occurring, or whether any specific group of researches is central in a clump or only peripheral. We also have a measure of the manpower directly involved; and multiplying by the average salary or income of such men, sector by sector, gives the amount of money directly spent on supporting the scientific population. By sampling we can add to this, again sector by sector, the amount spent on auxiliary services and on buildings, libraries, apparatus, and machinery. Added together, we have the total expenditure on pure science together with the manpower involved, and the way the overall pattern compares with similar profiles for other countries and the world total.

• BUYING SCIENTIFIC KNOWLEDGE

Comparing these figures with national expenditures for research and development it becomes obvious that in many sectors money is being spent that does not correspond to an output in cumulating literature; it is therefore not purchasing scientific knowledge. This by and large is the expenditure on technology: new products, processes, and services. Here one is concerned with a set of particular products being purchased by the country for its military power, prestige, medical well-being, or industrial profit. It is possible to see how much one is paying for space science and how much for a lunar landing or communications satellite; how much for particle physics and how much for reactor technology. Of course there is some reciprocal relation between science and technology, but we have never managed to estimate any dependence accurately because all previous figures were lumped together.

• LOOKING AT THE DEVIATIONS

My final sample concerns deviations from the normal and standard exponential growth of science. Although the normal pattern is for doublings in size to occur every ten to fifteen years, several key examples indicate that new fields and new countries emerge by exploding into a vacuum at a much greater rate, while old fields and old countries act as if they are meeting with saturation conditions that make growth considerably slower than the norm.

A number of case studies now exist that throw new light on the birth of a field and the inception of a science in a newly developing country. The sudden developments of the initial phase are followed by rapid growth to a point where normal exponential conditions are maintained. In a study of late nineteenth-century Japan, it was shown that the crucial phase occurred with widespread reform of the educational system and a switch to teaching in Japanese as well as European languages. Such findings are directly applicable to policy problems of the developing countries.

It is, however, in the possibility of saturation conditions in some countries—notably the United States and the Soviet Union—that one finds the most provocative results of science analysis. One of the most pressing problems will very likely be that of the overdeveloped countries, where difficulties are already appearing, not only in the supply of high-talent manpower, but in the rapidly increasing costs of utilizing this manpower. Because of this deceleration the biggest scientific countries will automatically be taking a lesser and lesser place in the world total, with even more difficult choices than now as to how to deploy their resources and talents.

The basic problems in organizing science and technology are increasing very rapidly; we are headed for demands as urgent as those which faced the profession of economics during the financial crises of the great depression. With this demand in mind, I am most concerned that we make every effort to have ready some well-integrated and hard theory in the science of science.

Onward the Management of Science: The Wooldridge Report

NIH was not cleared on all counts by the Wooldridge Committee, which itself is rated low on methodology.

Joseph D. Cooper

After a year's survey of the research and management operations of the National Institutes of Health, a White House–appointed committee, chaired by Dean E. Wooldridge, reported to the President that (i) the scientific activities of the National Institutes of Health "are essentially sound" and that the public is getting its money's worth for the approximately $1 billion a year now spent through NIH; (ii) the *organization* and *procedures* of NIH must be changed in order to avert "substantial problems" in the future.

The Wooldridge report ["Biomedical Science and its Administration: A Study of the National Institutes of Health" (report to the President, February 1965)] was represented to be an effort to bring dispassionate, professional judgments to bear on questions pertaining to the future of NIH. The report is singularly free of the marketplace tone and stridencies of some reports to the public on health matters. In itself, this is a great gain. The substantive recommendations, however, while impressive, are likely to provoke spirited challenges. This, too, is wholesome, for progress is promoted by open, constructive dissent.

The substantive findings and recommendations of the Wooldridge Committee and its panels are discussed here, but they are, in a sense, of secondary importance. The larger question explored is whether the operation of the Wooldridge Committee itself should be taken as a suitable model for the conduct of future assessments of federal science operations. The President's Science Adviser and personnel of the Office of Science and Technology had hoped this would be one of the experiential outcomes of the Wooldridge Committee operation.

The creation of the Wooldridge Committee was one of the aftereffects of criticisms of NIH made by the Fountain Committee (the Intergovernmental Relations Subcommittee of the House Government Operations Committee, Representative L. H. Fountain of North Carolina, chairman). The Fountain Committee had charged that NIH had both committed and encouraged loose practice in grants management and that the university grantees had not assumed responsibility for prudent management of public funds. Although the Fountain Committee had not gone very deeply into appraisals of scientific quality, it had raised questions which some felt had to be resolved one way or the other.

Apart from this background, and its continuing implications, it had also become apparent that the time was at hand for a full-fledged review of NIH operations in the light of NIH's phenomenal growth. In the summer of 1963, therefore, President Kennedy directed the Office of Science and Technology to make the study discussed here, which got under way early in 1964 after the need for such a review had been reaffirmed by President Johnson.

Summary of Findings and Conclusions

In brief, the Wooldridge Committee made these findings and arrived at these conclusions:

1) The "large majority" of NIH intramural and extramural research is of high quality.

2) The large, centrally managed, collaborative research programs—the so-called "crash programs"—have not been well managed, have not produced gratifying results, and have not been well designed scientifically. The program of the Cancer Chemotherapy National Service Center came under particularly critical review.

3) The best available method for awarding research grants is through the study-section procedure, which utilizes scientific peer judgments.

4) The NIH needs urgently to strengthen its management capabilities, especially if it is to be able to assume growing responsibilities in directed research, demonstration projects, training programs, long-range planning, and the ensuring of optimum utilization of its funds.

5) Overall grants-management responsibilities of the universities must be stengthened. Where university action to strengthen grants management is not forthcoming, NIH should use its granting authority as leverage to "encourage" administrative improvement and to punish unresponsive universities.

6) The authority of the director of NIH should be strengthened while, at the same time, the autonomous status of categorical institutes should be diminished. There should be a strengthening of staff support for the NIH director, particularly in the area of program planning.

7) A new Policy and Planning Council should be created to assist the director of NIH in making of major plans and policies, especially those related to allocation of funds and resources. The new council should be encouraged by appropriations committees of the Congress to participate in the annual budget hearings.

8) The organizational stature of NIH should be upgraded by giving the director "easier access to and greater participation in the councils of higher authority in the Department of Health, Education, and Welfare," especially at the policy level of the Secretary.

9) The intramural program of NIH should be reviewed to assure that, for all activities, there is justification for conduct by the government. The report inferred that the desirability of government conduct of "independent, university-like research" is subject to question.

10) The present limitation of indirect project costs to an arbitrary

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The author is an adjunct professor in the School of Government and Public Administration, American University, Washington, D.C.

percentage of direct costs should be replaced by a new system. All costs, direct and indirect, should be itemized and, if less than 100 percent is to be paid, the same fractional reimbursability should be applied to both direct and indirect costs.

11) The investigator should be made to feel that his salary comes from the university. Accordingly, the costs included in a grant which are attributable to the salary of the investigator should be separately negotiated between NIH and the institution.

Several other recommendations were made, including the following.

The director of NIH should be given greater discretion for the transfer of funds from one category to another. This would permit him to accommodate unanticipated program needs and to use unexpended program balances in some areas for the relief of shortages in others.

The amounts of grants for the support of general research should be enlarged in order to give university administrative authorities greater control over the content and direction of research programs. These grants should be made available for science departments outside the medical schools.

In recognition of the increasing quantification of the biological sciences, NIH should encourage greater participation of physical scientists and mathematicians in all aspects of its operations.

The administrative executives of grantee institutions should be given authority to make a variety of project-related decisions at present reserved for central NIH determination.

Organization of the Report

Before commenting on the specific findings and proposals of the Wooldridge report, I want to discuss its organization. The document as a whole is 213 pages long. The committee's official judgments are contained in the first 49 pages. All else is addendum material with which the committee said it may or may not have been in agreement. These supplementary materials are the separate reports of the panels and special groups set up to advise the Wooldridge Committee.

The overall committee, consisting of distinguished educators, industrialists, scientists, and philanthropists, devoted itself to issues cutting across the NIH effort as a whole. Advising the Wooldridge Committee were 11 panel groups of which eight were devoted to the life sciences: the anatomy, behavioral sciences, biochemistry, biophysics, microbiology, pathology, pharmacology, and physiology panels. These, it will be noted, ignored the categorical organization of NIH research. To complete the list, there were an administration panel, a physical sciences panel, a review procedures panel, and a group of *ad hoc* panel members.

When any reference is made here to the findings, conclusions, or recommendations of the Wooldridge Committee, it pertains to material within the first 49 pages. Likewise, a reference to the "report" refers only to material in pages 1–49.

Whether or not it was so intended, this format permitted statements to be made and published without responsibility for them being attributed to the Wooldridge Committee itself. Some very strong statements were made in this way, including one on cancer chemotherapy and collaborative programs in general, and another on congressional involvement in such programs. The committee recommended a careful reading of individual panel reports, which serve also as state-of-the-art reports and projections. It should be noted, however, that on topics dealt with in common, the panels were not necessarily in agreement.

Some mention should be made of the relationships between panel members and NIH. The eight life sciences panels had, in all, 74 members, of whom eight were government employees. Of the remaining 66, 58 were listed in the 1963 research grants index of NIH as project grantees. From all 11 of the advisory panels, 38 members were listed in the 1963 edition of *Roster of Members of PHS Public Advisory Groups* (Public Health Service publication 262A). One member of the committee itself also was listed in the *Roster*. These project grantees and PHS advisers were asked to make assessments of the output of a system of project approval in which they were intimately involved both as grantees and as members of peer review groups. The defense given for this aspect of the system is the usual one: you simply cannot find many competent scientists who are not under NIH grant support and not members of study sections and other advisory groups. This is undoubtedly so. Still, it does not dispose of the subtle influence on judgmental processes which occurs when people who are part of a system are asked to review the products of that system. The report did not indicate that many panel members and advisers were either grantees of NIH or members of NIH or PHS advisory or review groups.

Notably absent from membership in the Wooldridge Committee itself or its advisory panels were prominent medical research men and others who have been influential in multiple roles as "citizen witnesses" before appropriations committees, as members of NIH advisory councils, and as participants in a number of national advisory bodies. This group includes such people as Michael DeBakey, Sidney Farber, Philip Handler, Isador Ravdin, and Howard Rusk, among others, who have carried a heavy load in these roles.

One explanation is that most of these people were already members of the President's Commission on Heart Disease, Cancer, and Stroke—a commission whose life span largely paralleled that of the Wooldridge Committee. In fact, Philip Handler of Duke University was originally to have been chairman of the biochemistry panel of the Wooldridge Committee but resigned when appointed to the President's Commission.

Is NIH a Science Agency or a Health Agency?

The Wooldridge Committee asserted that "NIH devotes its principal efforts to a broad program of investigation of life processes, rather than to a search for direct cure or prevention of specific diseases." The committee stressed the desirability of such a "normal science" approach and attacked the "head-on" approach as being "frequently the slowest and most expensive path to the cure and prevention of disease." Note that the Wooldridge Committee didn't merely state that this is how NIH should conduct its work. Rather, it asserted that this is the way things actually are. This fact, it observed, may not be generally understood. "Cursory reading of the various legislative acts that establish NIH powers and responsibilities would not make this point clear," stated the report. "Similarly, the employment of such labels as 'heart,' 'cancer,' 'neurological diseases and blindness,' and the like, in the titles of the major organizational units of NIH, suggests more of an orientation to specific diseases than actually exists. Although there are practical reasons for such an overemphasis on disease categories in the organization structure, it is not ideally suited to the kind of research programs which must actually be carried out. One of the accomplishments of the NIH management has been that of making a scientifically inappropriate organizational structure an effective arrangement for performing its real mission."

In short, the report states that NIH is not a disease-oriented organization. It is, rather, engaged in the support of fundamental research into life processes along normal disciplinary lines. While NIH justifies its programs to the Congress and to the public in terms of drives on various disease fronts, these are merely "practical" expedients through which NIH has to operate, stated the Wooldridge Committee.

A notable deficiency in this argument is any discussion of the overall mission of NIH. It would seem essential to go into this matter in some depth before making recommendations affecting mission. The Wooldridge Committee and its panels do present a concept of mission, which is for NIH to function mainly as an instrumentality for funding biomedical science organized along disciplinary lines. What seems to have been overlooked is that NIH is also a public instrumentality. Its growth up to its present dimension was made possible because forces of persuasion convinced the public that, through NIH and its categorical institutes, massive assaults would be launched against various disease entities. Whether or not this is best from the standpoint of normal science is an argument apart. There is still the serious matter of accommodating the expectations of the public. Besides, a persuasive case might also be made for disease-oriented research as having its own fundamental outputs. The classic example in this regard is the development of the poliomyelitis vaccine, a project of the National Foundation. From the standpoint of the public this was a successful outcome in a campaign against a specific disease entity. As viewed from a broader scientific standpoint this mission stimulated advances in virology which continue to have their referred and deferred effects, not the least of them being in connection with the possible viral etiology of cancer. There are, thus, many roads to Rome. The NIH travels many of them. It needs to do so in the future, to assure that progress will be balanced and rapid.

A related problem, hinted at tolerantly by the Wooldridge report, is the public posture of NIH in telling what it is doing. Is it proper to assume the role of disease chaser in the popular prints while playing the more correct role of fundamental researcher in scientific circles?

Assessment of Research Quality

The report's general endorsement of the quality of research "currently supported" by NIH seems to raise more questions than it purports to answer. There is, first, the overall question of the relationship between good management and research quality. Here we have a dilemma: if the quality of management has been deficient both within NIH and in the universities and if, nevertheless, research continues to be of high quality, why be concerned about good management other than to make sure that no funds are improperly diverted? On the other hand, it might be more realistic to ask whether there *can* be a consistently high level of research quality in the face of inadequate management.

Then there is the matter of the rate of growth of NIH appropriations as compared to the expansion of the scientific community dependent upon NIH. "Despite the tenfold increase in NIH support of research during the last eight years, there is no evidence of over-all degradation in quality of the work supported," stated the report. "On the contrary, there is good evidence that the average quality is steadily improving. This appears to be a consequence of a rate of increase in the production of competent biological research scientists matching the over-all rate of increase in research support." For this, the report offers no documentation. It takes from 10 to 12 years to double the scientific population. One must assume that in this doubling there is no more than a proportionate increase in numbers of scientists of excellence. One might well infer, to the contrary, that exponential increases in funding attracted marginal and submarginal investigators in some degree. This could be inferred from the fact that observations made just before the major period of NIH growth, which began in 1957, indicated that the supply of first-rate researchers was then fully committed. The Wooldridge Committee, in effect, concluded that a politically determined level of spending brought into being a corresponding number of competent scientists.

In raising these challenges I do not charge that NIH research, whether intramural or extramural, is not of high quality. I have no way of knowing. It does not seem, however, that the Wooldridge Committee satisfactorily disposed of the question.

The committee said that it had confidence in the validity of its conclusions about quality because of the competence and distinction of its consultants and the extensiveness of their survey. The committee went to considerable pains to explain the methodology of the survey, especially the statistical sampling method used with the advice and assistance of a panel of three distinguished statisticians. The committee did not, however, go into the question of whether the members of its advisory panels should have been asked to evaluate the products of a system of which they were a part. Nor did the committee reveal the criteria followed by panel members in reviewing research projects to determine their quality. It is understood that such criteria were given the various panel members, but part of the understanding with the institutions which were to be visited was that all project reviews and even the criteria pertaining to them were to be held confidential. It is an interesting point, for it raises a collateral question of public access to information about how public funds are spent.

The report stated: "Out of the 240 'traditional' extramural research grants investigated, the panel teams expressed serious reservations about 9 projects and adjudged an additional 7 to be unworthy of support. In scientific research, such a ratio of ill-advised projects, when judged after the fact, is impressively low. Much more frequently, NIH-supported work was found to set the national or international standard of excellence in its field."

One would hope that the statistical sampling was proper and that subjective factors in evaluation were not at work, for these figures are impressive. There remain the questions raised above. Also, the report did not include any comment on 268 other, nontraditional research grants also investigated. Neither did it draw attention to this selective subsampling.

If the findings on quality are to be believed, one must reevaluate the many, many criticisms of recent years to the effect that the scientific literature (the products of research) is bogged down by an abundance of trivia —bibliographical buildups, replications of work already done, and data of questionable value. While such allegations are subjective judgments, the fact that they are made by responsible individuals leads one to conclude that there must be something to them. Perhaps this is an area for a new committee to investigate.

The assurance of quality is further clouded by some knowledge of the realities of grantsmanship. It is fairly common knowledge that the right labels are often placed on the wrong bottles. Research projects may be designed to support a teaching position or a principal investigator who spends much or most of his time away from the university, discharging the duties of a "research entrepreneur" rather than those of a conductor of research. Moreover, it is a fact that the timing of a new research project is more likely to coincide with the need for maintaining a steady or rising state of staff support than with bursts of creativity. In themselves, none of these comments refutes the major finding on quality of the Wooldridge Committee. Rather, these questions are raised as gross challenges because the scientific community is left in the dark as to the nature of the criteria of review.

On a related matter, the Wooldridge Committee endorsed wholeheartedly the peer-judgment mechanisms of approving requests for research awards. The committee and its review-procedures panel were almost lavish in their praise of the panel system. The question raised here, however, is whether the Wooldridge Committee addressed itself to the pertinent issue—that of whether the panel mechanisms can be strengthened, not of whether they are necessary.

The stream of criticism which has been directed in recent years against the panel mechanism by Alvin Weinberg and others has been to the effect that panels, for all their virtues, tend, through cults of personality, to inhibit progress. The Elliott Committee pointed to the growth of a "panel establishment." The consensus of past constructive criticism has been that panels could stand more membership rotation than they actually have had. The Wooldridge Committee did not, however, deal with this problem. Moreover, scant attention was given the role of advisory councils in project review. There was a time when advisory councils were able to review projects individually because there were fewer projects than there are now. In fact, during the earlier days of NIH growth, descriptions of new projects were published in the appropriations hearings. Now, advisory councils rarely examine individual project proposals.

One other study which dealt with the panel situation was that of the Kistiakowsky report [National Academy of Sciences, Committee on Science and Public Policy, *Federal Support of Basic Research in Institutions of Higher Learning* (1964), George Kistiakowsky, chairman]. The request for this study was made in a resolution of the American Society of Biological Chemists and other scientific groups as a direct response to the activities of the Fountain Committee and the actions it had obliged NIH to take. The principal contribution of the Kistiakowsky report was to call for strengthening of weaknesses in the panel system through which research proposals are evaluated and to call for new types of research support to correct imbalances.

Criticisms of Collaborative Research

The criticisms of the quality of collaborative research must be considered within the framework of the larger thrust of the Wooldridge Committee and its panels. This larger objective appears to be that of bringing more firmly under the outside academic establishment the control of the federal effort in biomedical science—that is, to make this effort conform to the academic disciplines. As mentioned earlier, the committee insisted that the most rapid progress against specific disease entities is likely to come not from organization by disease categories or from crash programs but from continuing inquiry into the life processes. Hence, it is understandable that all the recommendations of the Wooldridge Committee on the conduct of science are oriented toward the values of the academic establishment.

On the other hand, the committee's criticisms of science programs are concentrated on the products of what NIH staffers call The Establishment, consisting of a mutually reinforcing group of "citizen witnesses," key members of congressional appropriations committees, key officials in the executive branch, and the leadership of the Mary Lasker organization (a philanthropic group which concentrates on expansion of federal health programs). The citizen witnesses are those who testify before the appropriations committees; who dominate the advisory councils and the occasional commissions on growth of the enterprise; and who were responsible for the inception of at least several of the crash collaborative research programs, in particular the cancer chemotherapy program.

One can undoubtedly find much support in the scientific community for criticism of the collaborative research programs. "NIH is experiencing difficulty in achieving the results desired from its large collaborative activities," stated the report. "In particular, many medical scientists question whether the value of the Cancer Chemotherapy Program, which accounts for more than half of all Collaborative Program funds of NIH is commensurate with its cost. We advocate the appointment of an *ad hoc* committee to make a study of this program and to recommend any necessary changes in direction."

A subpanel of the Wooldridge Committee said of the Cancer Chemotherapy National Service Center: "Because the availability of money exceeded the availability of sound ideas, some unsatisfactory effects inevitably resulted. . . . We believe . . . that the CCNSC should have been taken through an extensive pilot project stage before its full-scale launching." This is not a new idea; opponents of the mass trial approach took the same position when the cancer chemotherapy program was first being debated. They were, however, overruled because of continued pressures by Establishment members.

The committee noted that the current budget for cancer chemotherapy is approximately $34 million a year but that related projects bring the total to approximately $47.5 million a year. Even at the lower figure, the committee noted, this is the lion's share of all NIH collaborative research, which in fiscal year 1964 was $58 million. The suggestion was that some of the money spent on cancer chemotherapy might more constructively have gone for other pursuits.

Although the committee did not make specific critiques of other collaborative research programs, it identified several of them. The Psychopharmacology Service Center received no mention at all. It was explained that this program had not been picked up by the sampling procedure. This is regrettable since the psychopharmacology program has been so vigorously touted by certain Establishment members as to command a great deal of public interest. A review of this program would reveal difficulties of a different kind from those found in the cancer chemotherapy program. In some respects the problems are even more critical, for they involve the quality of research on human subjects. One wonders, also, why the collaborative project on perinatal disease received no comment, since it is open knowledge that it is in trouble.

The Wooldridge Committee criticized the National Cancer Institute in particular for having dropped outside advisory consultants from the cancer chemotherapy program. The NCI said it did so because it found that some of its professor-consultants had too many conflicts of interest. That is, in addition to being professors they were consultants to drug companies, often had proprietary interests in drug enterprises, and were advising the National Cancer Institute on the awarding of contracts to enterprises in which they had interests. The Wooldridge Committee felt, however, that NCI took advantage of this situation in order to divest itself of outside consultants. The committee felt that NCI could have found acceptable advisory panel members.

The committee reaffirmed the desirability of having collaborative programs as a function of NIH but listed certain prerequisite conditions.

1) Use of outside experts to advise on the feasibility of proposed collaborative programs.

2) Exercise of an advisory review by the proposed Policy and Planning Council for all major collaborative programs.

3) Contracting flexibility to permit the NIH to turn over program-management responsibility for collaborative programs to outside organizations, when justified.

4) A policy of keeping each collaborative program as small as possible.

5) An inviolable rule that no large collaborative program will be started until a strong management team is available, regardless of how scientifically promising the program may be.

6) More dependence on continuing appraisal and advice by outside scientific consultants than has recently been the case.

There is a suggestion to the Congress that it desist in future from directing the setting up of various crash programs. While the committee itself avoided direct comment on this, one of its subpanels said: "The Congress should not be disenchanted of biomedical science by the seeming slowness of progress toward specific goals."

The subpanel then suggested that when the Congress identifies health priorities it should defer to the judgments of outside peer groups. Some criticism of both crash research programs and the categorical-disease approach to biomedical research is implicit in the panel's call for "a catholic attitude to recognize that discoveries made in the pursuit of one health problem can often be exploited to yield answers for a second health problem even before the first one has been solved."

Strengthening University Management of Science

The criticisms of the management of science programs both in NIH itself and in its grantee institutions come within the realm of normal expectation. A scarcity of managerial maturity seems to have become a concomitant of progress in practically all areas of science and technology as well as in the professions generally. One can even say that the professional manager who looks to the problems of others is often himself in need of repair, like the preacher and the cobbler. While this is a rationalization, it is not a justification for not doing something about problems once they have become identified. Moreover, in the NIH situation the problems have been aggravated by an unusually steep curve of growth.

The solution proposed by the Wooldridge Committee to enforce the upgrading of grants management in the universities is for NIH to use its grant-making leverage to compel good practice. "In the absence of adequate administrative improvement, NIH should substantially curtail the amount of its support for the institutional investigators," said the report. One can think of nothing that is more likely to raise the academic hackles than for NIH to say to a university: "Either you straighten out and fly right or we'll cut your grant support levels." After all the charging and countercharging that came in the wake of the Fountain Committee report, to the effect that it was urging interference with academic freedoms, the Wooldridge Committee proposal for direct federal intervention comes as something of a shocker. In fact, the classical argument against the federal grant-in-aid approach is this: first you woo them with money; then you get them to like its feel: and then you begin to impose conditions for their continued receipt of your money. By that time you begin to own them mind and body.

Centralizing Authority in NIH

The proposals to centralize authority in the director of NIH and to provide him with staff facilities for enhancing his program-planning capabilities should be considered in the light of previous patterns of NIH organizational growth. Most of the pressure for NIH expansion came from outside. The creation of both the Cancer Institute and the Mental Health Institute, the first two categorical institutes established within the overall hegemony of NIH, came about through outside pressures. Thereafter, other categorical institutes were added, each with its own outside supporters and beneficiaries. In the same way, collaborative research programs were superimposed on this structure, all without regard to any grand design which would assure balance and integration of effort. Each of the categorical institutes has its own statutory authority, its own appropriations, its own advisory council *responsible to the Surgeon General*, and its own group of citizen witnesses.

A natural fear on the part of the scientific community is that centralization of planning and authority in the hands of the director of NIH could lead to a monolithic, authoritarian bureaucracy. Just as academicians in the universities resist the imposition of authority by their own administrative officers, so NIH scientists in the categorical institutes would be likely to object to an authoritarian structure. In this, they might well be supported by their outside academic colleagues, who could be expected to say, "Though the present leadership consists of 'good guys,' who might succeed them in the future?"

Certainly the Wooldridge Committee did not have in mind any such developments. Rather, it sought a redress of balances to enable the NIH director to exercise an overall responsibility for programs where, before, his resources for such purposes were extremely limited. Nevertheless, the proposed concentration of authority is a change in the power structuring of NIH which would have to be brought off with consummate skill in order to preserve the advantages of decentralization, fragmentation, and scientific pluralism within the framework of overall planning.

A corollary proposal is to create a Policy and Planning Council which would advise the NIH director, review major new program proposals (especially proposals for collaborative research programs) and, if the Congress is willing, provide budgetary advice. Of course, the proposal has merit, for there is now no overall advisory council to which the NIH director can turn for guidance. There is, however, the risk that a new elite group could thereby be created which might dominate a less independent personality than the present director, James A. Shannon. This, of course, is no reason for not embracing the proposal. Rather, the argument comes under the heading of customary caution.

The Wooldridge Committee made a point in advancing the principle of providing independent "advice" (rather than governance) to the NIH director. It went further in suggesting a specific mechanism, and in urging its expeditious creation. It might also have suggested viable alternatives, but it did not do so.

What is likely to provoke more than merely spirited reaction behind the scenes is the suggestion that Congress turn to a new source of scientific guidance in the development of its own budget judgments pertaining to the NIH. As the proposed Policy and Planning Council would consist of experienced and distinguished scientists in addition to a minority of outstanding nonscientists, one possibility is that its members could supersede the individuals who comprise the so-called "professional judgment budgets" upon which the House Appropriations Subcommittee relies. As a source of judgments its members could supersede the citizen witnesses upon whom the Senate Appropriations Subcommittee relies. One cannot imagine that a shift in the locus of exogenous power would be effected very peacefully. At the very least one might expect a lively competition for membership on the new council, if it should be established and if it should bring about a shift in locus of informal elite power.

Organization of NIH

The proposal to give the director of NIH greater access to the highest councils of the Department of Health, Education, and Welfare was left vague, presumably because of ongoing studies of HEW-PHS-NIH structure. On the one hand there seems little doubt that the phenomenal growth of NIH within the framework of the Public Health Service has created organizational problems. It is probable that, as the scope of health programming in the federal government broadens further, many separate agencies will become operationally involved. This lends support, perhaps, to current proposals to establish a Department of Health. On the other hand there are arguments for bringing NIH, the Office of Education, and the National Science Foundation organizationally closer together, because of their common interest in building up the academic establishment.

One related question not touched upon at all is the distinction between functions of NIH and of the National Science Foundation. The original concept for NSF was that it would be a source for the funding of free, nonmission-oriented research, including the broad area of biomedical science. The overall thrust of the Wooldridge Committee would seem to be in the direction of expanding what should be an NSF capability, as stated in the NSF charter, through the structure of NIH.

This may be the time to consider other holdover issues. For example, should the Division of Biologics Standards remain in NIH or should it be combined with the Food and Drug Administration, with which it should have greater homogeneity of interest? The National Institute of Mental Health is becoming extensively involved in the conduct of community action programs; this suggests the possibility that it has outgrown NIH. Unlike the other categorical institutes, it is heavily involved in the politics of federal-state relations. One possibility might be to retain within NIH, as a research organization, only those activities which are of an academic-research nature, relating to the biological bases of mental disease, psychopharmacology, behavioral phenomena, and related work.

The suggestion that NIH might be divested of at least some of its intramural activities calls for the most careful consideration. The Wooldridge Committee said that it "is not convinced that it is sound for the Federal Government to conduct large amounts of scientific research of the kind that non-Federal institutions are equipped to carry out," and that "a majority of the NIH intramural program appears to be of this nature." The NIH intramural scientist is described as having at least as much "academic" freedom as his university counterpart, and probably more. Furthermore, he is described as having fewer "red-tape" annoyances and fewer distractions such as faculty meetings, department administrative assignments, committee activities, and the like. "Not being in an educational institution, he need not teach; he can devote all his time to research." The lack of teaching responsibility as a possible partial basis for the development of the large intramural establishment was examined by the Wooldridge Committee. "Nonteaching positions in basic health research are certainly not common, and perhaps there is here a legitimate hole for the government to fill in the nation's health science structure. However, we suspect that the size of this hole may not be very great."

The most obvious comment one could make is that nonteaching positions on a *de facto* basis are plentiful throughout the academic community. Why the lack of teaching responsibility at NIH should be a matter either for implied criticism or for envy is difficult to understand, unless it is that NIH intramural researchers don't even have to pretend they are teaching. As for NIH scientists' being relatively free of administrative and bureaucratic distractions, one has but to try to get some of them on the telephone. He will discover how universally their time is consumed in attending meetings, fulfilling administrative requirements, and so on and on.

If anything, NIH scientists are to be commended for their concentrated adherence to purpose in the face of financial disadvantage. In contrast, their academic colleagues, in many or most cases, can avail themselves of consulting and summer research opportunities which bring them substantial incomes in addition to their base salaries, which already exceed those paid by the government to their scientists, the latter situation being a historic reversal. Ironically, it is NIH fund-granting which has helped bring this about.

The only action on the intramural issue called for at this time by the Wooldridge Committee is a study by the proposed Policy and Planning Council, although the report goes quite far in intimating what might be the outcome of such a study. What the committee did not bring out is the fact that the intramural program has escaped criticism to a singular degree. It is one of the bright spots in the NIH firmament. The committee suggests that the intramural staff members have little impact on the extramural programs, and that such an impact cannot be used as an argument for maintaining intramural activities at present levels. If this should actually be the case (the committee did not document this statement) it might be desirable to enhance the intramural scientist's role as reviewer and consultant in grant-making.

One can see other reasons for having a strong intramural capability in considerable depth. Thus, the national interest might well be served by having a series of independent research units which are free, as the intramural laboratories are, of the preoccupations and maneuverings associated with "grant-swinging." Furthermore, the Wooldridge Committee has not made a case *against* the idea of having an independent type of research organization, with no teaching obligations, nor has it made a case for a virtual monopoly of research by the universities. One could, in fact, muster arguments in behalf of having more independent research organizations dissociated from the universities. Admittedly, these considerations were outside the frame of reference of the Wooldridge report, but they bear on the intramural issue.

The "enrichment value" of a strong intramural program seems not to have been considered. This is a value the committee could not readily identify or weigh. Nevertheless, it would seem logical to argue that a strong intramural program, which includes advanced work by distinguished scientists, helps in recruiting and retaining the total NIH staff, both intramural and extramural.

In a pluralistic system, such as science should be, there is some value, also, in having as many independent points of view as possible. If NIH is to build up its overall planning capability it will need to have contributions from both its intramural and its extramural staffs.

Payments to Universities

The indirect-cost issue has been festering its way through a seemingly endless series of investigations and reports by the scientific establishment, the Congress, and the executive branch. The Wooldridge Committee, in a new approach, now argues that it is unfair and unrealistic to distinguish between direct and indirect costs. In other words, all incoming work adds to the burden of overhead, which then must be funded in some way, usually through diversion from other university programs. The committee suggested that ordinary industrial accounting practices be followed. All overhead costs would be allocated to direct costs in arriving at total costs to be charged to the customer. If the customer—the federal government—then wants to pay less than 100 percent of total costs it should do so across the board, not distinguishing between direct and indirect costs. Presumably the university would then be able to budget the aggregate load of research it could support if it must make a matching contribution.

The proposal that salaries of investigators not be included in the research grant proposal deserves careful study. The reasoning was dual: the investigator should not be demeaned by having to negotiate his own salary with his professional peers; his loyalty to his own institution would be strengthened by having his salary more dependent on the negotiations of the latter with the NIH. While this proposal may be in the right direction, the niceties would need careful engineering. It would seem that salaries within a university need to be considered within *its* total pattern.

Conclusions

Progress is being made, undoubtedly, in the development of mechanisms for assessing federal science operations. One must conclude, however, that the Wooldridge Committee approach does not serve as a model for the future. The committee did not avoid built-in biases of interested parties in selecting its advisory panels. It did not publish the criteria it used in making assessments of research performance. It did not propose alternative actions. It did not provide adequate documentation either to support its own findings and recommendations or to enable readers to make independent assessments.

Finally, any study of NIH can be little more than a fleeting view of a moving scene. New program dimensions generate new relationships and, in turn, new stresses and strains. Minor difficulties become major ones. Old problems fall out. The full implications of the proposed regional medical complexes, recommended by the President's Commission on Heart Disease, Cancer, and Stroke, are yet to manifest themselves. One of the issues engendered by this proposal is, Who shall administer the new research funding for the medical complexes? Whether or not this is to be done through NIH is yet to be decided. (At the time of writing, the HEW conclusion was that NIH should have this responsibility.) In any event, new patterns of funding academic research are likely to emerge—together with new problems.

National Planning for Medical Research

Philip Handler

Let me say at once that I do not advocate the synoptic planning attempted by the systems analysts, or the balanced growth which is frequently taken as a prime desideratum, but, instead, recommend that those who plan a national medical research enterprise exercise skillful opportunism as they stimulate the growth of the system by relatively disjointed increments.

At first approach such planning seems simple. A small nation with limited resources of funds, facilities, and manpower need merely decide which is the most important biomedical problem in its part of the world and then direct those resources to solution of that problem. An economically well-developed nation, with substantially greater resources, might consider simply giving the entire system free rein in the expectation that its scientists will attack those problems which are important and approachable experimentally. Later, in retrospect, one might assess what had actually been accomplished. But neither approach is really acceptable. All the considerations which have been raised with respect to the allocation of some fraction of a nation's total resources to the biomedical research enterprise are equally appropriate when one attempts, in turn, to fractionate that enterprise. Accordingly, the problems posed by biomedical research in the smaller or less-developed nation *are* more simply managed than are those of the more complex nations. One cannot but feel that control of schistosomiasis or of frank malnutrition, for example, where these are endemic, is of overriding importance. Surely these much more properly command the attention of those concerned with the public health in such areas than do the more universal problems of heart disease, cancer, or genetic disorders.

For those responsible for decisions under such circumstances, I have but one counsel. Every research enterprise flourishes best when the group which is so engaged attains some meaningful, critical mass. Hence, a nation with one or two medical schools should seriously consider the possibility of developing only a limited number of research groups, each addressed to a problem of maximal concern to that nation and each large enough and so equipped and financed as to afford some prospect of success. Such success will not only have immediate relevance to the public health of the area but will effect a marked enhancement of morale and create an intellectual and political climate of richer opportunity for subsequent endeavors.

Only a handful of major clinical triumphs, such as the eradication of pellagra, penicillin therapy for syphilis, general antibiotic therapy, treatment of arthritis with steroids, and the recent accomplishments of vascular surgery, have, in the United States, served as catalysts which have opened the public purse for support of biomedical research. Those nations which, of necessity, can at present expect to mount only relatively more modest biomedical research enterprises may find it best not to engage competitively in those aspects of medical research which are under intensive investigation elsewhere. I do not mean to imply that individual scientists in smaller nations cannot successfully compete, for example, in molecular biology. Nor do I suggest that the scientists of the emerging nations must mark time for decades as they retrace from its beginnings the long evolution of medical research. Quite the contrary. The scientist born in one of the emerging nations but trained in one of the older laboratories and with access to current literature need suffer no handicap save the limitations of his own talent and of the resources which his society places at his disposal. Nevertheless, unless he can be joined by a sufficient group of competent colleagues, I believe he will best serve his own ends and those of his nation by addressing himself to a problem of unusual significance in his own locale.

Internal and External Pressures

The 2nd NIH International Symposium on Biomedical Research has emphasized the concept that, for science generally, two significant sets of pressures determine the allocation of resources: pressures which arise from within the scientific community and those which arise from without (*1*). This concept is equally applicable to the allocation of resources within the biomedical enterprise. The pressures from without are easily identifiable. They include the general aspiration to free man of cancer, of heart disease, of infection, of malnutrition, of fears in the night; society expects, and quite rightly, that much of the total research effort shall be directly devoted to these ends. They include the expectation that the biomedical community will operate an educational system which will produce physicians in sufficient numbers to provide adequate care for all members of society. They include the expectation that those engaged in research will reproduce their kind in numbers sufficient to assure an adequate continuing supply of individuals who will pursue medical science. And it is gratifying to recognize that they include a growing expectation that man will intensify not only his exploration of the universe in which he finds himself but his exploration and understanding of himself.

The internal pressures, generated by the research community itself, are less widely experienced but, unless modified, more likely to give direction to

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The author is James B. Duke Professor of Biochemistry at Duke University, Durham, North Carolina. This article is adapted from an address presented 1 March 1965 in Williamsburg, Virginia, at the 2nd National Institutes of Health International Symposium on Biomedical Research.

the conduct of research. For example, if left to its own devices, a substantial segment of the biomedical community is likely to eschew the immediate problems of disease. Some may enjoy the esthetics of enzyme kinetics, while ignoring metabolic disease; others may explore viral genetics, while ignoring the consequences of viral infection. Or, some wisp of the Zeitgeist may lead many to examine the mechanisms of carcinogenesis while none seek insights into the bases for schizophrenia. In sum, the scientific community continues to press for the vitality and expansion of the relevant scientific disciplines and for biological research at its most fundamental levels, preferring to defer direct attack upon overt disease until, in its view, the stage has been adequately set. In general, I share this approach.

It is the obligation of those charged with the responsibility for what is euphemistically called "planning for science" to be aware of both types of pressure, to admit that each is a valid criterion for decision making, and to recognize that neither set of pressures, alone, constitutes a sufficient basis for national decisions.

The Extreme Views

To be sure, each extreme view has had its exponents. At one extreme are statements such as that by Michael Polanyi (*2*), who argues, "No committee of scientists, however distinguished, could forecast the further progress of science except for the routine extension of the existing system. The pursuit of science can be organized, therefore, in no other manner than by granting complete independence to all mature scientists. The function of public authority is not to plan research but only to provide opportunities for its pursuit. To do less is to neglect the progress of science. To do more is to cultivate mediocrity and waste public money." The adherents of views such as this are numerous, and history documents their claims. Indeed, in only a handful of instances has organized society recognized a major problem and directed to it the scientists who found an appropriate solution.

In this country, for example, our Public Health Service recognized the threat posed by pellagra in our Southeast and dispatched Joseph Goldberger to investigate the problem. His triumph is now history, but it is rather ironic that, having prejudged the nature of the problem, the Public Health Service dispatched a bacteriologist to address himself to what proved to be a nutritional problem. And if this tale has any moral it is that the triumph reflected the genius of the investigator rather than the wisdom of those charged with allocating the then meager resources of the U.S. Public Health Service. How many instances of societal planning of successful major advances in the elucidation of human biology or in the understanding, prevention, or treatment of disease can one add to such a list? The development of Atabrine, understanding of the etiology of retrolental fibroplasia, the development of antiviral vaccines, and control of insect-borne diseases are among the relatively few such major, planned accomplishments. The development of new drugs by the laboratories of the pharmaceutical industry, an arm of organized society, must also be included.

On the other side of the ledger—that of the unplanned accomplishments which we owe entirely to the imagination and initiative of individual investigators—is virtually every other major advance in man's understanding of himself and of the disorders to which he is subject. Surely this history indicates that the criteria for research support which arise from within the scientific community are generally valid. In fairness, however, let it be said that large-scale public support of research and the opportunity to "plan" are recent phenomena, and this judgment must be held in abeyance.

Nevertheless, many concur with Hogben (*3*), who said, "To get the fullest opportunities for doing the kind of work which is worthwhile to themselves, scientific workers must participate in their responsibilities as citizens. Among other things, this includes refraining from the arrogant pretense that their own preferences are sufficient justification for the support which they need. This pretense, put forward as the plea that science should be encouraged for its own sake, is a survival of Platonism. Science thrives by its applications. To justify it as an end in itself is a policy of defeat."

Such statements engender much controversy—and properly so. Patently, modern society supports the laboratory of a scientist not so that he may amuse himself but, rather, in the hope that his activities will, in some measure, make possible realization of one of society's own expectations. To be sure, these expectations include, broadly, the advancement of knowledge, but this ranks well below the hope that the scientist's findings can soon be translated into some practical end. Accordingly, in this country we have attempted to manage a national enterprise which provides opportunity both for the scientific giants whose research, freely undertaken, results in "quantum jumps" in our understanding and for those scientists who seek to exploit such understanding in the common interest.

In our own time it has become apparent that planned science—here I use the term *planning* rather broadly—*is* feasible. There have been no planned breakthroughs, nor are there likely to be any. But there can be and there has been planned exploitation of such breakthroughs. Not even Fleming planned his astute observations, but the subsequent effort required to produce penicillin and to determine its structure was most effectively planned. Society did not plan Enders' observation of viral propagation in animal tissue in culture, but society did plan the large program which supported the development of effective antiviral vaccines. Society did not plan the observations which led to the strong suspicion that elevated concentration of serum lipid is related to the development of atherosclerosis and myocardial infarction, but society can and does plan the effort necessary to validate that conclusion and to develop means for alleviating this disorder. Watson and Crick were free scientists, engaged in a problem of their own choosing, but society could and did plan to support the broad-scale effort required to amplify their hypotheses, in the hope of bringing understanding of those phenomena which underlie genetic disorders of man, viral infectivity, and perhaps cancer.

But the administrators of science must not plan the *doing* of science. They can but plan *opportunities* for the doing of science and hope that talented, competent investigators will avail themselves of such opportunities. Effective planners may not do less and should not do more.

Planning a Research Enterprise

It becomes apparent that, in attempting to plan a national biomedical research enterprise, one must view the enterprise while simultaneously considering each of a series of seemingly independent parameters. Among these are the various diseases which ravage mankind, perhaps the organ systems of which man is built (liver, kidney, brain, and so on), the continuing vitality of each of the related scientific disciplines, and the integrity of the academic institutions in which much of the research is to be performed. One must weigh the relative importance of research done on man himself and research performed on animals or model systems; of research in the laboratory and research in the field; of research in areas clearly identifiable as "biomedical" and research, essential to an understanding of life, in tangentially related disciplines; of the support of research and the support of training for the future conduct of research; of the support of research and research training and the support of education in clinical medicine; and of hosts of seemingly lesser parameters. Each of these parameters is relevant to each decision concerning the planning and funding of individual research programs.

At this point one might visualize the development of a matrix in which each parameter has a weighted value and is brought to bear on each decision; this would be an idealized version of the approach of the operations or systems analyst. Successful development of such a matrix would seem to suffice for the total planning operation, and all one would then need to know would be the total appropriation to be made available by the state in any one year; all other decisions would then be automatic. This is an exaggerated version of what Charles V. Kidd has termed "allocation in multiple dimensions." In the exaggerated form here presented it is rather horrendous to contemplate and, no matter how conscientiously or painstakingly developed, is guaranteed to yield many decisions which time will prove to have been incorrect.

In a limited sense, however, the principle does have merit. Those encharged with planning responsibility must indeed be aware of the various criteria which are meaningful in the decision process. They must assure society that none of the meaningful parameters have been neglected, although they cannot possibly guarantee that a perfect balance among them all has been assured. Indeed, such balance is not even necessarily desirable.

Happily, in the real world, matters can proceed more easily and more successfully than the novice in planning might have thought. No nation has actually engaged in such detailed allocative planning. In most instances planning has been done, rather, in a single dimension. Resources have usually been allocated by disease or by discipline, or, in nations with university grants systems, have simply been apportioned among universities and other appropriate institutions. But for our purposes it is important to note that the other dimensions do exist, whether they are planned for or no. Each research project which is supported, or for which support has been denied, has relevance in virtually every possible planning dimension. And, in annual retrospective examination, it is imperative that the operation of the system be examined in as many dimensions as possible, so that, if necessary, corrective action may be taken. One can hope in this way to assure that certain broad priorities are operative. Probably highest among these is the assurance that, at all times, a future generation of investigators is being trained and that their number bears some reasonable relationship to the desired future magnitude of the national research enterprise. Second priority might be given the assurance that all the disciplines currently meaningful on the biomedical scene are given sufficient support to assure a vigorous national effort. Third priority might relate to the vitality of academic institutions and of individual laboratories. In fourth place might be the distribution of resources by disease categories, ranked in the order of the severity of such disorders in a given community. The fact that it is this fourth priority which is frequently given most obvious expression relates to political considerations rather than to the internal logic of the system.

It will be evident that in a nation confronted with a planning problem of this magnitude there *already* is a system in being which can be retrospectively examined and corrected. Indeed, much of what is called planning is essentially remedial in that it seeks to rectify apparent errors rather than move toward planned objectives. Planning proceeds from an existing base, and each proposed increment to the existing system can be considered rather readily from the multidimensional standpoint.

Allocations and Adjudications

These thoughts, lead, then, to consideration of the actual process whereby one establishes allocations within a budget and then adjudicates the competing claims of individuals or institutions within some category of that budget. Patently, this cannot be done in an information vacuum. The establishing of allocations is the more complex task, as it demands a weighing of the values of the internal and external pressures. These pressures certainly vary among nations, and in any one nation they must vary from time to time. In any case, they can only be designated as weak, strong, or paramount. Thereafter one requires real data descriptive of opportunities: knowledge of the number of competent investigators interested in a given area, of the physical facilities, of the number of students in training, and of the cost of doing business in a typical research group; and, most importantly, an assessment of the "state of the art" in each subfield of research endeavor—that is, an informed guess concerning when the time is right, conceptually and technologically, to increase significantly the level of effort in a given research area. Evaluation of this information and appraisal of the scientific field should permit tailoring of the demands of the scientific community to the interests of society. They yield a crude determination of the relative magnitudes of support to be given, for example, to fellowship programs, arthritis or dental research, genetics or pathology, clinical or basic research.

Such considerations are particularly germane to those components of the system which are properly called "small science"—science in which the individual professor or senior investigator and his coterie of junior colleagues are the meaningful productive and budgetary unit. Whether he works in a government-operated establishment or in a university where his work is supported by a national research grants program is inconsequential. When the funds available are less than those requested by the scientific community (and this should always be the case, else excessive funds have been provided), competing requests can be evaluated only on the basis of intrinsic scientific merit—that is, the competence of the investigator and the imagination, soundness, and feasibility of his proposal. The evaluation can be made only by a jury of his peers, drawn from a national panel of experts. To be sure, they may share his enthusiasm for his discipline but they are not rivals, on his local scene, for prestige, salary, space, or influence. It is the lack of this evaluative process which is the cardinal weakness of a university grants system and of other purely bureaucratic administrative devices. Conversely, it is the operation of this evaluation system which is the best guarantee that society will get its money's worth.

Proposals for "big science" are rare in biomedical research. They must be examined closely both for their intrinsic value and for the harm they could do the rest of the system through imposing a drain on manpower, facilities, or funds. By and large they are foreign to the university biomedical community, and, if they are desirable at all, their operation is a proper function of government or of a contractor-agent.

The greatest advantage of incremental planning is the fact that such planning makes it possible to seize previously unforeseen opportunity. And it is here that the quasi-mathematical approach to total planning fails most seriously, since it does not take into account the manner in which science itself grows. Let us consider this in some detail.

Balanced and Unbalanced Growth

There is a great temptation for those engaged in planning to attempt to project systems of "balanced growth." Indeed, "balanced growth" has been the acknowledged objective of most of those who plan a nation's economy, its weapons systems, and its support of science generally as well as its support of biomedical research. Although planners frequently recognize that they cannot realize this ideal, this so-called balanced system is the proximate objective of their development programs. As noted by Hirschman and Lindblom (*4*), the basis for this ideal is a "faith in the existence of basic harmonies similar to the Greek belief that the truly beautiful will possess moral excellence as well." It seems opportune, therefore, to direct to your attention a recent series of papers which have taken striking exception to the concept of planning balanced growth of a large enterprise and have advocated in its stead a process which has been called "disjointed incrementalism."

Because the analogies are pertinent to the problems here considered, it seems appropriate to summarize the views of various members of the group who advocate this process. For example, Hirschman (*5*), an economist, has offered as the basic defense of *un*balanced growth the concept that an economy's resources should not be considered as rigidly fixed in amount. He argues that more resources or factors of production will come into play if development is marked by sectoral imbalances, since these will arouse private entrepreneurs or public authorities to action. In the present context, there are many analogies. For example, the existence of a large pool of investigators who lack facilities for their activities constitutes a pressure which, ultimately, will result in the construction of new and more adequate facilities. The appearance of large numbers of young men and women desirous of training in biomedical research results in pressure which leads to the development of fellowship and training programs. Recognition that a temperate bacteriophage can disappear into the genome of the host bacterium, be reproduced with that genome for many generations, and then reappear in vast numbers under adverse circumstances prompts many investigators interested in the nature of the viral origin of cancer to take a new tack in their explorations. As Hirschman has said, to the extent that the imbalance is self-correcting through a variety of mechanisms, unbalanced growth may propel the economy forward jerkily but also more quickly than by planned, balanced expansion.

Klein and Meckling (*6*), students of development policies for weapons systems, allege that a given development is both less costly and more speedy when marked by duplication, confusion, and lack of communication among people working along parallel lines. They argue against early attempts at integrating subsystems into a well-articulated, harmonious general system. They advocate, instead, the full exploitation of fruitful ideas regardless of their fit to some preconceived pattern of specifications. The principal basis for this attitude is the very fact of uncertainty. They note that the first configuration to be developed is, in any case, unknown, and that knowledge increases as some of the subsystems become articulate. Knowledge about the nature of any one subsystem increases the number of clues concerning the desirable features of another, just as it is easier to fit in a piece of a jigsaw puzzle when some of the surrounding pieces are already in place. What is important is to develop the pieces; one can adjust them to each other later. This view argues for maximum support of the current enthusiasm for molecular biology even though its immediate clinical application seems remote, and for vigorous follow-up of clues to the possible viral pathogenesis of cancer even though the major psychoses remain enigmas and relatively few biologists seem to be immediately concerned with their elucidation. Similarly, it argues for full support of all the competent scientists in our midst, even though this results in overcrowding of their laboratories.

Lindblom (*7*), who has been concerned with general aspects of policy making, takes as his point of departure a denial of the general validity of an assumption which is implicit in most of the literature on policy making—that there exists sufficient agreement to provide adequate criteria for choosing among possible alternative policies. This assumption is often questioned in contemporary social science, yet many of the most common prescriptions for rational problem-solving follow only if it is true.

Conventional descriptions of rational decision-making include the following steps: (i) clarification of the objective or values; (ii) survey of alternative means of reaching objectives; (iii) identification of consequences, including the side effects or by-products of each alternative means; and (iv) evaluation of each set of consequences in the light of the objective. However, Lindblom notes that such synoptic attempts at problem solving are not possible when, for example, clarification of objective founders on social conflict, when required information is not available or is available only at prohibitive costs, or when the problem is simply too complex for man's finite intellectual capacities. Most importantly, it does not logically follow, Lindblom argues, that when synoptic decision-making is extremely difficult it should nevertheless be pursued as far as possible. Hence he suggests that, in many circumstances, substantial departures from comprehensive understanding are not only inevitable but desirable. I cite his thesis in detail because the analogy to me seems so close.

Working Principles

I have summarized the case for what may be called "semi-planning." What are the working principles of this approach? A few major notions are worthy of consideration. (i) An element of laissez-faire, with its attendant duplication and gaps, may well be desirable rather than abominable. (ii) Orderliness, balance, and detailed planning may be more satisfying to the planners than to the society they serve; some matters probably ought to be left to what has been called "a wise and salutary neglect." (iii) It is unwise to specify detailed objectives in advance when the means of obtaining them are virtually unknown. (iv) A rational problem-solver wants what he can get and does not try to get what he wants except after identifying what he wants by examination of what he can get. (v) Arrangements must be established whereby decision-makers are made aware of, and can react promptly to, emerging problems. (vi) Long-range planning is a valuable exercise, but long-range plans for a research enterprise which is the sum of many smaller research programs are of dubious validity.

These principles, taken in part from Hirschman and Lindblom (4), approximate a real world which is almost invariably characterized by unbalanced, not balanced, growth. It is the above-scale salary offered to the new appointee which is the surest guarantee of an increase in the scale. It is the existence and success of the National Science Foundation which provides the platform on which stand those who argue for establishment of a National Humanities Foundation. Instances of the principle that imbalance results in pressure for a correcting growth are commonplace. And these same principles seem entirely germane to the planning of a national biomedical endeavor which is as inherently sporadic and random as is the natural growth of science itself. Indeed, the hallmark of the competent investigator is that he seeks constantly to identify the most important problem which can be attacked with the technology currently available and limits his goals accordingly. But his attention is continually given also to developments within his own and related disciplines. He is quick to apply new information, new techniques, new apparatus. In short, he brings to research his imagination, his knowledge, and his technical know-how, and he combines these with what may best be described as a "skillful opportunism."

In my view, those responsible for the management of a national enterprise which is the sum of such individuals must do likewise. They must continually assess the major parameters of the enterprise for which they have responsibility, continuing the attack on the major public-health problems, insuring the vitality of the classic scientific disciplines and recognizing the emergence of new ones, insuring the training of new investigators and practitioners, and safeguarding the health of the medical schools and universities. The total system may then be nourished and made to grow, but by disjointed increments. For example, given a 10- or 20-percent increase in total funds, one should almost never expand support, across the board, of all existing programs by this 10 or 20 percent. Instead, one should take advantage of significant, albeit unplanned and unexpected, new knowledge of human biology or pathology, of the work of new investigators as it appears, of new approaches, new drugs, new apparatus, new facilities, new architecture, and newly awakened public interest, always utilizing the skillful opportunism characteristic of the individual investigator.

Goals may be set only in the broadest terms of ultimate objectives—for example, a general homotransplantation, effective cancer chemotherapy, a rational management of viral infections, genetic transformation as therapy for hereditary disorders or the prevention of atherosclerosis. And one can, in a general way, plan *for* the tasks ahead by providing the necessary physical plant, stimulating activity in biomedical engineering, and providing a sufficient number of specialized facilities such as animal colonies, hyperbaric chambers, and libraries. It is highly doubtful that the planner can wisely do more; he will fail in his responsibilities if he does less. And he must ever be mindful that the planning of science must be left to the working scientist.

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THE
YALE REVIEW
VOL. LIV · PUBLISHED IN OCTOBER 1964 · NO. 1

BIOPOLITICS: SCIENCE, ETHICS, AND PUBLIC POLICY

BY LYNTON K. CALDWELL

LAST year a front-page column of the New York *Herald Tribune* carried a whimsical description of a new science of biopolitics. J. P. Miller, already secure in his reputation for social criticism through satire in *Days of Wine and Roses,* recounted an imaginary interview between an official government biopolitician and a newspaper reporter concerning the meaning of the "new science" of biopolitics, "the science of proving that what must be done for political reasons is biologically safe for the human race."

The reported interview occurs sometime after 1971, when the collapse of the nuclear test ban treaty has been followed by a resumption of massive testing in the atmosphere and soaring levels of fallout. In order to relieve popular fears and prevent panics and anti-government demonstrations, official biopoliticians "prove scientifically that the previous human tolerances to radioactivity and all other by-products of nuclear testing, including strontium 90, had been estimated far too low." The official pronouncement has "a wonderful calming effect on the people." Public confidence is restored.

But, asks the reporter, suppose that an increase in bone cancer is being caused by heavy concentration of strontium 90 in human and animal marrow? Some unofficial scientists say so. But the official biopolitician replies that statements which frighten people are certainly not in the public interest. Bone cancer and strontium 90 cannot be linked, he declares. "The people wouldn't like it. Therefore, by definition it is biopolitically impossible."

In the tradition of the moralizing fable, Miller is posing one of the biggest, most difficult questions of our time: are science and politics really compatible? The philosopher-dramatist with a sociological turn of mind can put the question this way. Presumably the political scientist could too—but he rarely does. As "scientist" he finds it impractical to ask questions about the extent of man's political capacities that the present state of knowledge does not permit him to answer. Moreover the discipline of political science in America has, in its subconscious, assumed the infinite perfectibility of man. To hypothesize that political man cannot or will not reshape his goals and values in the light of scientific knowledge seems disloyal to the tradition of the discipline. But while the question cannot be usefully posed in absolute and theoretical terms, it is by implication being posed daily in limited and practical situations. In the language of politics "it is a condition that confronts us, not a theory."

An explosion of biological knowledge and technology is raising questions of public policy which until recently were hypothetic, and were therefore from a practical point of view unreal. Whether there is, can, or should be in any sense a science of "biopolitics" can easily be dismissed as facetious. But the conscientious man grows uneasy when he reflects upon the mounting problems which the life sciences (in particular) are posing for political solution. There is certain to be more biology in politics and this could mean, as J. P. Miller implies, more politics in biology.

The scientist, the politician, and the philosopher, each in his own way, is confronted by the question of how political reactions to an expanding, innovating biology will affect its application to the public happiness and welfare. And unfortunately for the policy-makers, happiness and welfare do not always follow from the same course of action. Yet there are urgencies in our present "biopolitical" state of affairs that compel a reconciliation of ethical values and scientific facts in public policies involving the biological nature of man.

"Biopolitics," then, though it certainly does not designate a science, is a useful piece of shorthand to suggest political efforts to reconcile biological facts and popular values—notably ethical values—in the formulation of public policies. It affords a selective focus on a portion of the larger issue of the relationship of science to society.

For several decades, spectacular developments in the physical sciences have overshadowed major but less readily demonstrable advances in biology. Moreover the impact of applied biology upon society often occurs on a time scale that obscures its effects—at least in the early stages. Thus the present population explosion has been underway ever since public health administration and medicine began to eliminate the "natural" controls over human reproduction. The explosion of population may be as inexorable and destructive as the explosion of nuclear energy, but the consequences of the nuclear bomb are all too readily observable whereas the potential consequences of the population bomb are inferred through the dry and less convincing medium of statistics.

Although there is widespread and profound disagreement as to its implications, the population explosion is now generally acknowledged. There is less awareness of a concurrent explosion of biological knowledge, an accelerating geometrical expansion of knowledge, the culmination of long years of accumulating inquiry in the various bio-sciences. It is the contemporary convergence of these two explosions—of people and biology—that justifies, indeed necessitates, a focus on biopolitics.

If the popular press and political behavior are taken at face value, people are nowhere (certainly not in America) ready to cope either conceptually or politically with the population explosion. This circumstance in itself is a major element in a larger body of evidence suggesting the unreadiness of most peoples and their governments to deal effectively with an impending explosion of biological knowledge. That extraordinary advances in biological science and biotechnology are imminent seems certain. To this there has been informed and responsible testimony for some time. Detlev W. Bronk, President of the Rockefeller Institute, has stated that ". . . we have learned more about the nature of living matter and the mechanisms of living organisms during recent years than in all prior human history." And the rate of learning accelerates. The revision of man's perception of himself and of nature that the biological sciences may require could be as drastic as the changes made by the physical sciences in man's perception of the cosmos. William K. Wyant, Jr. recently noted the likelihood that "the rough jolts of the future, in the way man thinks of himself, will come from studies done with the microscope."

The more sensational speculations growing out of biological congresses make news headlines and sober editorials. Commenting on the unprecedented implications of the emerging biotechnology discussed at the Eleventh International Congress of Genetics, an editorial in the New York *Times* declared that "the moral, economic and political implications of these possibilities are staggering" and then asked rhetorically "is mankind ready for such power?" In the judgment of some of the most thoughtful students of man's biopolitical behavior the answer is "No." Representative of misgivings in the scientific community is the regretful observation of Theodosius Dobzhansky that man, comprehending the meaning of his biological evolution:

> . . . should be able to replace the blind force of natural selection by conscious direction, based on his knowledge of nature and on his values. It is as certain that such direction will be needed as it is questionable whether man is ready to provide it. He is unready because his knowledge of his own nature and its evolution is insufficient; because a vast majority of people are unaware of the necessity of facing the problem; and because there is so wide a gap between the way people actually live and the values and ideals to which they pay lip service.

Public unreadiness to use an expanding biotechnology wisely is not merely a speculative conclusion. Popular behavior and political action (or inaction) indicate prevailing attitudes toward biological realities. A cursory look at some of the current biopolitical issues suggests a mixed and contradictory picture. In each case a confrontation of biological facts, political exigencies, and ethical values occurs in the course of policy-making.

Biopolitical issues tend to fall into two general groups differing chiefly in the directness and generality of their effects. The first group may be termed environmental. Issues in this category arise when environments are impaired as a consequence of deliberate or inadvertent human action. The most dramatic of these concerns radio-active fallout. The attendant confusion of counsels and political recriminations hardly need comment. Whenever biological innovation is believed to threaten public health and happiness, and when scientific evidence can be marshaled in support of opposing views, a biopolitical row is inevitable. The fluoridation controversy, chronicled recently in the *Saturday Review,* is a case in point. Another is the danger of chemical poisoning through pesticides, dramatized by Rachel Carson's *The Silent Spring,* which engendered controversies described by René Dubos as ". . . disgraceful both from the scientific and social points of view."

Biopolitical controversies, frequently as heated, have arisen over efforts to conserve scientific and esthetic values in natural landscapes and in plant and animal wildlife. More recently questions concerning the effects of noise and of crowding upon human populations have been pressed forward. But in none of these matters has public policy making been pursued with the vigor urged in most of the polemic and some of the scientific literature. Perhaps this is because a clear and unequivocally right course of action seldom emerges from the research findings and the contradictions of scientific and of popular opinion.

For this failure to deal effectively with environmental problems the scientific community bears some responsibility. In a recent critique on environmental biology René Dubos takes his fellow scientists to task for gross neglect of ". . . the problems posed by the response of the total organism to the total environment." He argues that the potentialities of medicine for human welfare will be severely restricted until medical science has been provided with adequate scientific knowledge of "the effects of the total environment on the human condition." When scientists themselves offer no adequate explanation of the responses of body and mind to the impact of modern technology, has the politician any choice other than to trim biological facts to fit political circumstances? If science cannot speak authoritatively regarding the threats to physical and mental health posed by "constant and unavoidable exposure to the stimuli of urban and industrial civilization; by the varied aspects of environmental pollution; by the emotional trauma and often the solitude of life in congested cities; by the monotony, the boredom, indeed, the compulsory leisure of automated work," how can the politics of these issues be guided by science? It may indeed be argued that science, and biology in particular, are providing society with a powerful array of tools and problems, but with no adequate conceptual basis for relating tools to problems in practice.

A second group of biopolitical issues are more directly and specifically physiological than environmental. More personal in immediate impact although scarcely less general in ultimate ramification are biopolitical issues relating to individual human behavior in the use of cigarettes, tranquilizers, narcotics, and alcohol—and extending to the biochemical control of personality. Even more personal and at the same time of greater social implications are questions relating to human reproduction, to social concern for the numbers and qualities of future populations. In addition, ethics and biology become mutually involved in the political issue of public responsibility for public health and medical care. And finally the relations between biology, politics, and ethics are perhaps most starkly posed in the issue of biological warfare. In few of these areas have people demonstrated a readiness to be guided by verifiable knowledge in a search for policies equal to the problems. On many matters, inadequate as our knowledge may be, our failure to make full use of what we do know is all the more regrettable.

Biopolitical problems—particularly the major ones—grow increasingly national, international, and even global in character. The continuing flow of air and water and living organisms around the world has always tended to spread biological phenomena into any receptive environment. Modern technology multiplies and accelerates these possibilities, but it also enables us to discover and to understand the processes of dispersion and interaction. Where cause-and-effect relationships in these processes have become clear they have sometimes influenced political behavior as, for example, when the sciences of epidemiology and plant pathology led to the establishment of quarantines at national frontiers and were among the factors leading to international cooperation in public health and agriculture. Continuing difficulty in controlling international traffic in narcotics and the recent tragic consequences of the sale of the dangerous drug thalidomide in international commerce underscore the lesson that there can be no biopolitical frontiers.

A convincing argument can now be made that old-fashioned political nationalism is one of the principal obstacles to biological sanity. How much positive harm or deprivation may a nation lawfully inflict upon the rest of the world in pursuance of its alleged "sovereign rights"? Atmospheric testing of thermonuclear devices has posed the question dramatically, but a list of other major biopolitical issues, current and impending, could be extended to great length and in great variety. Obvious illustrations are found in national policies pertaining to the destruction of wildlife, allocation of water from international rivers, disposal of harmful wastes, control of plant and animal diseases, and increase in populations.

The inadequacy of conventional political mechanisms to deal with the problems of the new age of biology is nowhere more apparent than in the oceans from which life may well have come and from which man is increasingly drawing sustenance. As knowledge of the influence of the oceans upon terrestrial life continues to grow, so too does apprehension concerning impairment of their life-sustaining qualities. Massive discharge of untreated biological and industrial wastes into rivers, lakes, and coastal waters has impaired or destroyed important resources of food supply and recreation; residues from oil-burning seacraft have been so harmful to marine life that international control efforts have been sought; and proposals to bury radioactive wastes in the sea have aroused fears and controversy. But deliberate pollution is not the only problem. The Surgeon-General of the United States Public Health Service reports that the insect-killer DDT in some mysterious manner has invaded the water environment of the world and is being found in surprisingly large concentrations in the fats and oils of deep sea fish.

But the most portentous biopolitical issues relate to the evolution of man himself. The coincident and related explosions of human population and of biological knowledge may conceivably represent the most critical stage in human evolution since the last great ice age. The ability and necessity to control the numbers and hence (in some respects) the genetic characteristics of future populations could create a situation without precedent in human existence. And, in addition, the availability and refinement of chemopsychiatric drugs suggests both hoped-for and frightening possibilities for the manipulation and control of human behavior. Never before have the necessity and the possibility of control over man occurred at so decisive a conjunction.

Popular (and political) "wisdom" tends to avoid facing issues in advance of a compelling necessity. Questions as sensitive and confused as those just mentioned are especially good candidates for relegation to some indefinite future. But if society's ability to deal effectively with a problem requires policy decision *before* the matter becomes a compelling issue, then some means must be found to enable political action to anticipate the future. Practical biopolitics calls for a degree of foresight that the lexicon of conventional wisdom would term "theoretical." And practical democratic politicians find it difficult to persuade themselves or their publics of the necessity of dealing with tomorrow's uncertain problems when the self-evident issues of today press for attention.

At the root of these issues one finds the familiar dichotomies: fact and value, science and tradition, knowledge and action. If society moves ever more rapidly into an age of biology, how well can public leadership—scientific, educational, and political—

bridge the gulf between the realities of popular concepts and the realities of scientific fact? If a massive reorientation of popular attitudes would be necessary for society to benefit fully from the *present* state of biology, how much more orientation may be required to develop a popular receptivity to the biology and biotechnology of the emerging future? There are wide gaps to be bridged between the biological sciences and public policies, and present resources are not adequate to the task.

The building of a better bridge between science and society leads to consideration of four basic elements in the process. These are: first, prevailing perceptions of man's relation to nature; second, the meaning of science as interpreted by formalized education; third, communication between scientists and policymakers; and fourth, leadership toward a policy synthesis of scientific knowledge and ethical values. Whatever utility the concept "biopolitics" possesses is primarily in relation to this fourth element. But all four are ultimately interrelated.

It is commonplace that man's perception of himself in relation to his environment is influenced by his culture pattern. In cosmopolitan and dynamic societies, these perceptions may range widely, as they have for example in the history of the American people. But in the realm of politics and social policy, some perceptions prevail over others. And, with acknowledgment of the inevitable exceptions, it is generally true that man's perception of his environment has in the main been possessive, exploitative, and short-sighted. From science, society has more often sought technology than understanding. The eminent ecologist Paul B. Sears has said, "The power of applied science has been overwhelmingly employed to exploit space, while those aspects of science that could illuminate its wise and lasting use are still largely ignored."

Industrial man (which until recently meant Western man) has for the most part seen himself as separate from and outside of nature. From this inference he has frequently concluded that he may exploit nature with impunity and that where nature fails to meet his wants, science through technology will synthesize a substitute. As *The Wall Street Journal* optimistically editorialized with respect to man's insatiable needs: "Technology, as always, can serve them." There has also been in Western civilization a perception of man *in* nature and a belief that he should seek understanding of his true needs and welfare through science. But this has been a minor current in a mainstream that uses science as servant rather than as teacher.

How science is used depends in large measure upon how its meaning is interpreted in the processes of formalized education. Science has been a potent influence upon education, but educational theory and practice have also shaped the course of science. Today more than ever the development of science depends not only upon the amount but also upon the nature of the incentives and support accorded it in the educational structure. For example, progress in fields as apparently diverse as medicine, human relations, and city planning is currently retarded because of past neglect of the environmental sciences. Interpretation of the implications and the needs of science to educators and to the public at large therefore becomes a crucial element in the advancement of science as well as of society.

The expansion, specialization, and diversification of biology and of all other sciences multiplies the difficulties of communication. New sciences create a need for new syntheses to relate and interpret their findings. New interdisciplinary areas take shape to deal with the new questions emerging between diverging sciences. In time, many of these interdisciplinary areas develop into coherent disciplines—into new sciences—and the process of specialization and of divergent and emergent disciplines continues.

Throughout this process direct and meaningful communication between the highly specialized research scientist and the public-policy-maker becomes ever harder to achieve. Popularizers of science have appeared in response to popular need and interest. But their status is as uncertain as their role is difficult. The best of them may find careers in journalism and may win recognition among scientists for informed and competent reporting. But there is at present little room for them in the structure of formalized education even though the need for better communication between science and the rest of society is now widely recognized.

The problem of how to organize this communication is yet to be solved. This is perhaps because communication is not merely exchange of information. And information is itself more than mere data; it is data plus meaning, intended and understood. The possession of scientific knowledge holds no promise of its use in discovering the true needs of men or in serving the public happiness or welfare. There is need for more knowledge but even greater need for more understanding.

Development of valid and coherent concepts of man-in-nature requires an interrelating and a synthesizing of knowledge. It is a task of interpretative leadership.. Committees of specialists may assist the clarification and integration of knowledge, but synthesizing insights and perceptions more often originate in the minds of individuals who only then can become the expositors, the interpreters, and the advocates of a new view of man and nature. This mediating role between science, ethics, and public policy may be filled in various ways by persons from varied backgrounds—from the sciences, from professional education, from philosophy, religion, or public affairs.

Among the more effective intermediaries between science and ethics in political life have been those public servants who have in their own ways been "biopoliticians" in the best sense. These men and women have not only seen a relationship between scientific knowledge and the public welfare, but they have acted on this insight to influence the course of public policy. One may cite as examples Harvey W. Wiley's crusade for pure food and drugs, Hugh H. Bennett's lessons in soil conservation, and Ira Gabrielson's labors to substitute science for folklore in the management of wildlife. In each of these instances and in more that could be cited, scientific knowledge, a fundamentally ethical perception, and skill in communication were fused in effective policy leadership.

Granted that some aspects of biopolitics rest upon solid scientific support, the fact remains that we have not yet laid down a comprehensive biological foundation upon which a "science of mankind" can safely be erected. The scientific basis of biopolicy is fragmentary and will most likely remain so until the need for a comprehensive, verifiable, conceptual foundation for a healthful, creative, self-renewing society is more widely felt than it is today.

Better popular understanding of the biological factors in society should follow from a more accurate popular comprehension of science in the broadest sense. George Gaylord Simpson has pointed out the integrating role of biology among the sciences: life is the phenomenon to which all principles of science apply. In certain specialized areas of biology, notably in relation to agriculture and medicine, there has been a continuous flow of knowledge from the laboratory to practical application. The histories of the agricultural extension service and of the public health movement in the United States afford cases in point. But the dual explosions of population and biology create a much broader need for the desirable kind of biopolitics that has been so effective in particular cases. To achieve this objective may require new machinery in government. More certainly, it will entail changes in the structure and content of formal education and the addition of new elements to the career development of teachers and public officials who in the long run are among the principal architects of public policy.

It is neither possible nor necessary to examine here the ways in which the machinery of government might more effectively promote and utilize scientific knowledge. Relations between science and government have been analyzed at length and are under study by several Congressional committees. There is agreement in principle that government must be adapted to the new conditions wrought by science, but less agreement on what changes should be made. The United States Public Health Service's proposed Center for Environmental Health illustrates how the growth of knowledge calls forth new agencies to extend and apply that knowledge.

The changes in education that are needed to bridge the gap between biology and politics are more clearly evident. Throughout the modern world communication and understanding suffer greatly from gaps in the structure of education—gaps that appear with specialization and with divergence among the sciences and between them and the humanities. But even C. P. Snow's pessimistic analysis of "the two cultures"—the sciences and the humanities—does not postulate a gap that is unbridgeable. And it can be argued that the structuring of knowledge in Western society is a major factor in the cleavage that he has dramatized.

There is perhaps no *one* best way to obtain a more adequate communication among the disciplines and a more effective integration of related knowledge. Among the older disciplines changes in concept and emphasis may be needed as, for example, in geography where the discredited "environmentalism" of the past generation is being replaced by search for a more valid basis for understanding man-environment relationships. We may also need new disciplines to interpenetrate the older ones—to give us syntheses—to provide the form and substance of a more comprehensive understanding of man and nature. The beginnings of answers to these needs may be discerned in some aspects of the behavioral sciences and in the emerging environmental sciences—some, such as ecology hitherto relatively neglected; others such as biometeorology, regional economics and outer-space environmental research, relatively new in concept and method.

If the conditions for a better biopolitics require more realistic popular perceptions of man-in-nature, one way to assist this popular understanding is through the re-education and training of teachers, public officials, and opinion leaders. Updating and improvement of the teaching of biology has been for some time a subject for attention by the American Institute of Biological Sciences. The development of an awareness and comprehension of the significance of scientific developments by persons *outside* the fields of science is a different although related problem. Both developments are needed in strengthening the foundation for an enlightened biopolitics.

An important but relatively neglected avenue toward broader public understanding of science is adult education in its various forms. There is special need for an interpretation of science in its most fundamental sense to be built into career development programs for executive officials in government, business, labor, and the professions. Science (and particularly the biological sciences) has heretofore received comparatively little attention in these efforts, possibly because the relevance of the sciences to most fields of career development has not been fully appreciated. If mankind is rapidly confronted by unprecedented possibilities growing out of biological research and by increasing difficulties resulting from increasing populations, the need for biopolitical reorientation may soon gain a general recognition that it does not now enjoy. But this task of reorientation will not be done well unless the implications of biology can be reduced to terms and concepts meaningful for public policy.

To bring about an up-dating of the biopolitical understandings of teachers and leaders in public affairs, a valid conceptualizing, interpretative educational leadership will be needed. Some of the leadership may come, as it has, from government itself. More will need to come from the universities, the learned professions, and research institutes. For it should not be inferred that biology offers ready answers to all the problems it defines or its applied technology creates. Closing the gaps of knowledge and restructuring that knowledge for attack upon new or persistent biopolitical problems will be, even more obviously than it has already been, a multidisciplinary task.

Some eminent scientists have shown skill in relating science to social needs and ethical values. But these extraordinary individuals have been too few and too infrequent to accomplish unaided the task of bridging the gaps between bioscience and biopolitics, between science and society. The sheer mass and specialized complexity of expanding knowledge create a need for a systematic and continuing effort toward synthesis from which intelligible conceptualization and communication may be forthcoming. As yet the task is barely attempted and then in only a few places.

Does all this then imply the need for a "science" of biopolitics for purposes quite the opposite of those suggested by J. P. Miller? The answer is both yes and no. It is no if biopolitics is understood *only* as a new formal academic discipline to deal comprehensively with social applications of biological knowledge. This is not to say that such a discipline is unnecessary—or would be impractical—or that it could not be developed. We have been concerned here with the problems and the needs suggested by the term "biopolitics," with general approaches to solutions rather than with specific remedial methods. But if a science termed "biopolitics" is not specifically implied, the need should be evident for a more effective relating of the biological to the social sciences and of both to public policy and ethics.

Without the interrelation and distillation of scientific findings into issues amenable to political action, the gap between science and politics cannot be successfully bridged. Science as technology may be readily available to the lower and more routinized levels of administration. But at the higher executive and legislative levels of the governmental hierarchy where the broad public policies are formulated, the science most relevant to the issues will be more conceptual than technical. The impact of scientific thought upon public policy will in large measure depend upon its being expressed in terms meaningful to political and administrative practitioners. The legislator and public administrator must make their own policy syntheses, but they can do their jobs more effectively if the data relevant to these decisions have been organized and reduced to understandable terms. The case for aid to the administrator in his task of synthesis has been stated with exceptional clarity by Paul H. Appleby:

> Specialist after specialist pursues analysis; who pursues synthesis, or even pursues analysis with any sensible orientation to the larger function of synthesis? It is the synthesis which involves all the heavy burdens of practitioners, and these burdens are heaviest when the social action is most complex and most complexly environed. Synthesis becomes more and more important as one goes up the hierarchy, and more and more important as one moves from the relatively specialized fields of private administration to public administration.

This synthesis does not necessarily require new sciences. Ecology, for example, has long been an established if insufficiently utilized "organizing" science. Its further development and involvement with the social sciences could provide much of the needed synthesis. It also seems probable that new emphases will emerge in established disciplines, that interdisciplinary studies will increase, and that new formalized disciplines may emerge. New arrangements to facilitate interdisciplinary studies involving synthesis of the social and biological sciences and relevant professional fields—notably architecture, engineering, public health, and natural resources administration—are already under consideration in a number of universities. From these developments might come major contributions to the formulation of public policy in the years ahead.

"Biopolitics" therefore suggests a need that may be met in many different ways. It would be difficult to argue that existing educational resources are adequate. But because few educational needs can be shown to be fully served, the question will be asked: How important is this underdeveloped area of biopolitics in relation to other unfulfilled educational demands? Restating biopolitics in broader terms as study of the role of science in society, its priority is of the highest. We have been paying heavy and steadily rising prices in dollars, health, and happiness for its relative neglect, and have entered, inadequately prepared, upon a decisive test of our capacity to avoid becoming the victims of our own ingenuity.

The "condition that confronts us" calls for more than the mere tolerance of imaginative innovation in reshaping and accelerating the education of society. Tangible and timely encouragement is needed for pathbreaking efforts, for the ever risky tasks of synthesis, for the continuing development of creative individuals capable of conceptualizing and interpreting the issues that arise at the meeting point of science, ethics and politics. The study of biopolitics—whatever it may be called—requires an extraordinary fusion of understanding, audacity, and humility.

RENÉ DUBOS

Science and Man's Nature

The Shaping of Modern Culture by Science

Words have dictionary meanings, but more importantly they have undertones which are determined by the history, beliefs and hopes of the people who use them. The word culture, for example, denotes very different attitudes and contents depending upon the kind of civilization to which it is applied. For civilizations of the Arcadian type, based on the belief that life was happy in the past, the role of culture is to preserve and transmit experience and traditions as faithfully as possible. In contrast, civilizations of the Utopian type, which believe that happiness can be realized only in New Jerusalem, demand that culture prepare man for the mastery of nature and for the creation of a better world.

Most men, in any period of history, have been at times Arcadians and at times Utopians. There is no doubt, however, that the world as a whole is now losing its belief in Arcadia and that the concept of culture is changing accordingly. Whereas traditional civilizations put a premium on the transfer of beliefs and customs from one generation to another, modern societies tend to regard the heritage of the past as but a matter of entertainment for leisure time, and to consider that the forces which are creating the world of tomorrow are the really serious concern of culture. One of the consequences of this shift of emphasis has been the progressive recognition that the natural sciences constitute as legitimate a component of culture as the traditional knowledge of man, of his history, and of his artistic creations.

It goes without saying that many varied social forces other than science have played and continue to play an immense role in shaping modern life. The invention of tools and of agriculture by prehistoric man, the emergence of social groups and especially of large cities, the development of laws and of the various religions, are but a few among the non-scientific forces which have determined the evolution of human nature and of the ways of life. Today, however, science and the technologies derived from it constitute the forces which affect most profoundly the environment in which men have to function and to evolve. Either by choice or from necessity, the cultural evolution of man will be molded in the future by scientific concepts and technological forces. Even more important probably is the fact that science is accelerating the rate of environmental and conceptual changes.

The horse remained the most rapid means of locomotion until the invention of the railroad, but we have moved from the propeller to the supersonic aircraft in one generation. All civilizations have until recently considered the earth as the center of the universe and man as the highest form of life, but we now seriously think about ways of communicating with other thinking and highly evolved creatures that we assume to exist in many parts of the universe. Science is the most characteristic aspect of our civilization precisely because it provides the mental and physical apparatus for rapid changes in our ways of life and even more perhaps in our conceptual views of creation. Indeed, the tempo at which man changes the environment and his views of himself is now so rapid that the rules of conduct for the good life must be changed from one generation to the other. In many fields, the wisdom of the father is now of little use to his son.

The immense role of science in the practical affairs of the modern world is recognized by all, even by its detractors, but surprisingly its influence on culture is often questioned, even by its champions. The following statement is typical of this skeptical attitude concerning the modern mind as it confronts science: "Our lives are changed by its handiwork, but the population of the West is as far from understanding the nature of this strange power as a remote peasant of the Middle Ages may have been from understanding the theology of Thomas Aquinas."[1] I shall attempt later in this essay to consider some of the factors which contribute to the estrangement of the scientific enterprise from the human condition. But it may be useful to emphasize first that science has influenced modern thought and culture much more profoundly than is usually admitted. In fact, it is probable that most educated men have now incorporated concepts derived from theoretical science in their daily thoughts even more effectively than medieval or Renaissance Europeans ever incorporated Thomas Aquinas in their cosmologies or their ethics.

The rate of acquisition of new knowledge was so slow in the distant past, and indeed until the advent of experimental science, that ancient civilizations found it difficult to conceive of the possibility of progress. Men whose lives depended entirely on the course of natural events were bound to be more aware of the recurrence of daily and seasonal phenomena, year after year, than of the continuous process of change which we now take for granted. Seeing that natural events repeat themselves endlessly, they tended to extrapolate from these cosmic cycles to human history. For them, the myth of eternal return seemed to apply to the affairs of man just as it did to the cycles of nature and the motions of stars. The known conditions of the present seemed to them but one stage in the endless ebb and flow of events.

It is difficult, of course, to determine with precision at what time the myth of eternal return was displaced in the Western mind by the concept of progress, namely, by the belief in a continuous process of change toward a new state different not only from the present, but also from anything in the past, and hopefully better. The philosophical teachings of the Renaissance and of the Enlightenment certainly helped to formulate the concept and make it intellectually acceptable. But there is no doubt that the philosophy of progress became part of collective consciousness in the Western world approximately at the time when experimental science first began to prosper. Men like Condorcet or Franklin wrote of progress as a theoretical possibility, and placed their hopes for its realization in the future developments of science. However, it was the doctrine of biological evolution which eventually provided the theoretical basis for the concept of progressive historical change. The doctrine of evolution therefore provides one of the most striking examples of the influence of scientific knowledge on modern culture.

Few laymen, it is true, have an exact understanding of the scientific mechanisms involved in biological evolution. Nevertheless, practically all of them now accept as a fact that everything in the cosmos—heavenly bodies as well as living organisms—has developed and continues to develop through a process of historical change. In the Western world, most great religions have come to accept a progressive historical view of creation.

Enlightened laymen tacitly apply evolutionary concepts not only to living organisms and to man, but also to his social institutions, his customs, and his arts. Yet the general acceptance of this evolutionary view is rather recent, dating only from the post Darwinian era. Evolutionary concepts were still either ignored, ridiculed, or almost universally opposed less than one hundred years ago. In contrast, they appear so obvious today that most orthodox churches, political parties, and schools of sociology, history, or art, teach them and indeed make them the basis of their doctrines. It can be said without exaggeration that theoretical biology has thus introduced into human thought a new element which pervades all aspects of traditional culture.

Cosmology, or the physicochemical sciences, could probably be used just as well as the theory of evolution to illustrate how much modern thought is being influenced by scientific knowledge. But since I am a biologist ignorant of these fields, I must act here as a representative of the lay public whose views concerning the cosmos and the structure of matter are progressively being transformed by a kind of knowledge that I do not really understand. Like every human being, for example, I have been puzzled by the concept of the divisibility of matter. I cannot imagine that the division of matter into smaller and smaller fragments can go on indefinitely, but neither can I imagine how this division can come to an end since I can always carry out one further dividing operation in my mind. Fortunately, I begin to sense that this paradox is not entirely beyond human comprehension. Although I know nothing of the theories or practices of elementary particle physics, I can apprehend that when sufficient energy is applied to elementary particles in the big accelerators, the particles are changed not by a process of true division but by a transmutation of energy into matter; every particle can be transformed into any other if the energy applied is sufficiently great.

In the preceding paragraph, I have mentioned on purpose a kind of phenomenon completely foreign to my knowledge in order to illustrate the manner in which science becomes incorporated into the cultural tradition. Science shapes culture not necessarily through its technical aspects, but rather by providing new points of views and by facilitating new attitudes. That the earth is round, and that all living creatures that we know have a common ancestry, is not obvious either to my senses or my common sense, yet these concepts have become integrated in my daily thoughts and thus constitute part of the fabric of my culture. It would be surprising if the general concepts of elementary particle physics and of relativity theory did not in some way become integrated in the general culture of the next generation.

The integration of scientific knowledge into general culture will probably be accelerated by the fact that there is a wide public awareness of some of the basic assumptions of science. Many lay persons have come to realize that each particular field of science develops as if it were a self-contained structure, with its own body of facts and its own inner logic. Students of matter investigate elementary particles and the laws which govern the primordial stuff of which these particles might be but the transient manifestations; their information is derived from recent experiments in high energy physics carried out with the aid of complex hardware. Students of human evolution trace the origin of man, step by step, to some small creature which lived in trees at the beginning of the Paleocene period; their conclusions are derived from the comparative study of ancient fossils found here and there in many parts of the world. It is obvious enough that the structure of matter and the evolution of man constitute two fields of science which have developed independently, each with its own techniques, points of view and goals. In this light, it would appear as if there were no such thing as science, but only a multiplicity of unrelated fields of knowledge. But while it is a fact that each field of science has its own characteristics and displays its own pattern of development, it is also true, and probably far more important, that no incompatibility has ever been found between one field of science and another; the laws of one do not violate the laws of the other.

The remarkable compatibility between all fields of science, whether they deal with inanimate objects or with living things, has implications which affect deeply the culture of our times. The validity of these implications is supported by the fact that the various scientific disciplines strengthen each other when, perchance, they can establish contact. Despite the immense diversity of creation, we all accept that there exists in nature a profound underlying unity. The search for this unity provides the motivation for the lives of many different men, some who like Einstein search for it in general natural laws, and others who like Teilhard de Chardin would trace cosmic evolution to a divine origin.

So general is the belief in the unity of nature, and in the power of the scientific approach, that this method is now applied to most areas of human concern, from the natural sciences to the historical sciences, from the analysis of the human fabric to the appreciation of human arts, naive as it may be to hope that methods developed for the study of inanimate objects can be applied to the much more complex and qualitatively different problems of social human life. But despite their premature character, the attempts to apply the scientific method as used by the natural sciences to problems for which it is not suited are of interest because they reveal a general awareness that we have under cultivation only a small area of the fields which can be exploited by science.

The Antiscience Movement

Since the various scientific fields include all the subjects on which reasonable men can converse objectively and exchange verifiable information, it is difficult if not impossible to state in words where science ends and where the humanities begin. The paradox, however, is that this semantic difficulty hardly ever causes any confusion in human behavior. The immense majority of the lay public shows by its reading habits that it sharply differentiates between science and non-science; this differentiation also appears in the fact that concert halls and art museums have more popular appeal than science exhibits. The "two cultures" may be an illusion, but in practice science is still regarded in our communities as a kind of foreign god, powerful and useful, yes, but so mysterious that it is feared rather than known and loved.

It is healthy to acknowledge that scientists themselves generally behave like the lay public when they function outside their areas of professional specialization. The student of plasma physics or of plasma proteins is not likely to select books on marsupials for his bedside reading, nor is the organic chemist inclined to become familiar with problems of population genetics. Most scientists, it is true, are interested at present in radiation fallout and in the hidden surface of the moon, but so are many members of the Rotary Club. Winston Churchill, Pablo Picasso and Ernest Hemingway are much more frequently discussed at the luncheon tables of scientific research institutes than are the Nobel prize winners in physics, chemistry, or biology of the same generation. And if Linus Pauling or Robert Oppenheimer is mentioned, it is less likely with regard to either's achievements as chemist or physicist than because their behavior makes them interesting and vital human beings. In brief, while scientists are deeply committed to their own specialized fields, they generally turn to non-scientific topics when they move outside their professional spheres.

The priority of general "human" concerns over purely scientific interests acquires particular importance in education. Whatever historians and philosophers of science may say concerning the fundamental similarities between science and the humanities as intellectual and creative pursuits, the high school or college student soon discovers from his personal experience that the two kinds of learning and activities are different as far as he is concerned. He will probably like one and despise the other; and science commonly loses in the comparison. A recent study of high school students selected for extremely high scholastic aptitude (only one per cent of the total student population!) revealed that the percentage of those selecting science decreased from 37.77 per cent in 1958 to 28.87 per cent in 1963.[2] Even more serious was the finding that among those who had originally selected science 55.2 per cent of the males and 58.9 per cent of the females changed to other fields during their college years. The significance of these figures becomes the greater when it is realized that the trend away from science occurred during a period when great social pressure was being exerted on young people to induce them to go into scientific careers.

The difficulty of scientific courses, and the shortage of gifted scientific teachers devoted to the training of undergraduates, may account in part for this disturbing rejection of science. But to be satisfied with such obvious explanations seems to be unwarranted, and unwise. At the risk of oversimplifying the problem and exaggerating its gravity, I incline to the view that the attitude of the lay public and of many young people toward science is at bottom one of hostility arising from anxiety. In my opinion, this anxiety is in part the result of a breakdown in the system of relationships between human nature and the scientific creations of man.

Throughout this essay, the expression human nature is used in the French sense of *nature humaine*, which encompasses much more than does the English phrase. By human nature I mean not only the instinctive, psychological and moral attributes which are characteristic of man, but also all the physiological needs and urges which are woven into his very fabric, and which he has retained from his evolutionary past. In other words, I shall have in mind man's total nature rather than the limited aspects of it usually denoted by the expression human nature. In the light of this larger view of man's nature, it may be easier to understand how scientific knowledge, although it enables man to manipulate his environment, paradoxically leaves him an outsider in the world he is creating.

While man is progressively mastering nature, his own nature has not so far surrendered to the scientific and technological onslaught.

Mankind has, of course, always known anxiety. The doctrine of original sin may well be merely a symbol for the uneasiness man experienced when he first realized that he was alienating himself from the rest of creation. From ancient times many have been those who believed that the world is out of joint, and it is not at all certain that their percentage numbers are larger than in the past. What is beyond doubt is that the gap between man's nature and the rest of nature is constantly becoming wider, hence the ambivalent attitude of modern man toward science. He wants the benefits of scientific technology, but he feels uneasy and indeed apprehensive about scientific knowledge *per se.* Despite much writing on the miracles of science, public fear and mistrust of scientists is probably on the increase and is certainly becoming more vocal. More and more frequently the emphasis is on the potential dangers of technological innovations, and even on horror stories concerning them.

The attitude of uneasiness has been increased, of course, by the fear of nuclear warfare, and of certain technologies which threaten the health of man. Popular articles entitled "The truth about. . . ." almost uniformly refer to the dangers of medical and technological procedures, and hint at the social irresponsibility of scientists. However, the origins of the antiscience movement are more complex and more profound than would appear from recent developments. There was already much talk of the "bankruptcy" of science during the 19th century. Science was then accused of destroying religious and philosophic values without substituting for them any other guide to behavior, or any convincing picture of the universe and of human destiny. This dissatisfaction is pungently expressed in Dewey's warning that "a culture which permits science to destroy traditional values, but which distrusts its power to create new ones, is destroying itself." The malaise has now extended to the scientific community itself, as recently acknowledged in a public lecture by a distinguished professor of chemistry in the United States. "Science is only one branch of philosophy . . . if we do make claims for support because of our rather immediate relation to industrial technology, we may well be making value-judgments concerning technology that we are, by virtue of our training, ill-equipped to make."[3]

Admittedly, the meaning of the word "value" is so poorly defined that most scientists would probably deny that it has any usefulness as a basis either for discussion or for action. Yet, the word is so charged with the hopes of mankind, its impact on the relationships between the world of science and the rest of society is so great, that it must be recognized as a real force. I would not presume to formulate values or propose a solution to the dilemma stated by Dewey. I shall instead limit myself to a consideration of several aspects of the scientific enterprise which contribute to its progressive estrangement from the human condition, and thereby to incoherence in modern life.

Man and his Future

A symposium entitled "Man and His Future" was held in London in 1963. Its purpose was to examine the consequences of the fact that "research is creating and promising methods of interference with natural processes which could destroy or could transform every aspect of human life which we value."[4]

The participants in the symposium found it rather easy to discuss the role of science in several current problems, such as: how to feed the billions of hungry people in the world; how to maintain an adequate supply of raw materials and of energy; how to accelerate the process of learning; how to prepare man for space travel. There was a tacit agreement among them that by using the proper scientific approach "almost everything one can imagine possible will in fact be done, if it is thought to be desirable." In contrast, the participants found no basis for common discourse when the discussions turned to the physical, psychological, emotional, cultural, or ethical traits which are desirable for human betterment. Indeed, the sheer diversity of views concerning what constitutes the good life led one of them to conclude that the only possible social policy for science as well as for human institutions was "piecemeal social engineering," that scientists must forego ambitious social plans and dedicate themselves instead to limited goals.

History shows, however, that human institutions cannot merely drift if they are to survive. Each civilization is characterized by the special kind of problems which it elects to emphasize. Furthermore, all societies operate on certain assumptions, and move toward certain goals. Despite our pathetic attempt at objectivity, we as scientists are in fact highly subjective in the selection of our activities, and we have goals in mind when we plan our work. We make *a priori* decisions concerning the kind of facts worth looking for; we arrange these facts according to certain patterns of thought which we find congenial; and we develop them in such a manner as to promote social purposes which we deem important. The most sweeping assumption in our communities at the present time is that the good life will automatically emerge if we focus our scientific efforts on the production of things and on the manipulation of the body machine, even though a large percentage of scientists probably believe that such an attitude is responsible for incoherence in technological civilization.

One might argue, of course, that incoherence is not objectionable *per se*, that incoherence may even be a symbol of intellectual integrity, and a necessary condition for the evolutionary development of mankind, since no one knows how to formulate either the ultimate truth, or the good life, or even the intermediary goals on the way to these ideals. In practice, however, there are limits to the amount of incoherence that man and his societies can tolerate; the popular success of anti-utopian and anti-scientific literature at the present time may indicate that we are approaching the breaking point.

I shall attempt in the following pages to discuss several disturbing aspects of the interplay between man's nature and the environment created by scientific knowledge. First to be considered will be the fact that, while the external environment and the ways of life are being revolutionized by technology, biological man remains fundamentally the same as he was when he emerged from his animal past. Outwardly, man makes adjustments to the new conditions of life; inwardly, however, he has so far failed to make true adaptations to them, and this discrepancy creates physiological and psychological conflicts which threaten to become increasingly traumatic.

Another cause of incoherence in our societies is that modern knowledge, especially scientific knowledge, relates less and less to human experience. In many cases, the technical apparatus of knowledge reaches into aspects of reality which are beyond human grasp. There is a disjunction between scientific knowledge and direct human experience.

Because science and technology are now advancing without the guidance of a well thought out philosophy of natural and social values, they achieve results and produce effects which in many cases no longer correspond to real human needs. Man, through science, has released disruptive forces which he has not yet learned to control. In front of his eyes, these forces are undermining the relationships slowly built through evolutionary processes between nature, the works of reason, and the hidden aspects of man's nature.

H. G. Wells pointed out in *A Modern Utopia* that ours is an adaptive civilization, incompatible with static social structures. Since we transform the external world through technology, we must also change our societies and ways of life because the maintenance of adaptive fitness is as essential for the survival of institutions as it is for the survival of living things. As presently formulated, however, evolutionary and social concepts give but an inadequate picture of man's relation to his environment. Their inadequacy comes from the fact that human societies and ways of life are rapidly changing while certain fundamental components of man's nature remain essentially unaltered.

Ever since the Neolithic revolution, man has become increasingly proficient in controlling the external world—beasts, forests, floods, climate, and many other natural forces. He has also developed enough knowledge of his own body and behavior to exercise some measure of control over certain obvious aspects of his life. Indeed, his confidence that he can modify and improve not only external nature, but also his own nature, constitutes the rationalistic basis for modern technological civilization. In Western countries, at least, technology has transformed the external world, medicine is learning to manipulate the body and the mind, social institutions are striving to establish universal respect for human dignity. Thus, ways of life are undergoing profound adaptive changes in an attempt to keep *social* man in tune with the rapid changes in the environment which are brought about by technological innovations.

In contrast, many important aspects of man's fundamental nature are not changing at all, or change so slowly that they are out of phase with the modern world. Biological evolutionary mechanisms are far too slow to keep pace with social evolution. For example, most functions of the body continue to exhibit diurnal and seasonal cycles, as well perhaps as cycles of other periodicities. Even though the ideal of technology is to create a constant and uniform environment, physiological functions still undergo cyclic changes because they are linked to the cosmic forces under which human evolution took place. When modern life carries the day into the night, maintains the same temperature and food supply throughout the year, and imposes rapid changes of latitude in a jet aircraft, it creates physiological conflicts because man's body machine continues to function according to the cosmic order. Anyone who travels by jet aircraft has a direct perception of the physiological disturbances caused in his body by the change of latitude. The immediate effects of the conflict between the paleolithic constitution of man and the exigencies of modern life can be documented by chemical, physiological and psychological measurements, but little is known of their long range consequences. There is no doubt, however, that many physiological disturbances have their origin in the conflict between the modern environment and the paleolithic ordering of physiological functions.

The so-called fight and flight response constitutes another manifestation of very ancient hidden forces which are still operating in modern man. It consists in a series of physiological and chemical processes which are rapidly mobilized in the body under conditions of threat, and which were certainly useful in the past. When prehistoric man encountered an enemy or a wild beast, a variety of hormonal processes placed his body in readiness either for combat or for running away. Today, the same processes are still set in motion under circumstances which modern man symbolizes as a threat, for example during social conflicts at the office or at a cocktail party. The physiological consequences of the fight and flight response, however, are no longer useful and indeed are probably noxious, since the proprieties of civilized life require the subjugation of the direct, physical response, and thus prevent the expenditure of physical energy.

Many other ancestral mechanisms which persist in modern man must find some outlet, even though they no longer correspond to a necessity of life. Just as a kind of hunting activity remains a need for the house cat even when it is well fed at home, similarly man has retained from his evolutionary past certain needs which no longer have a place in the world he has created, yet which must be satisfied.[5] Ancient civilizations were aware of the profound effects that hidden physiological and psychological forces exert on human behavior and they commonly symbolized these forces by a ferocious bull struggling against reason. In fact, most people have developed empirical procedures to let these occult forces manifest themselves under somewhat controlled conditions. As shown by Dodds in *The Greeks and the Irrational,* the Dionysian celebrations, the Eleusinian mysteries, and many other myths and rituals, served as release mechanisms for fundamental human urges which did not find adequate expression in the rational and classical aspects of Greek life; even Socrates found it wise to participate in the Corybantic rites.[6] Many such ancient traditions still persist in the advanced countries of Western culture, even though in a distorted form. In the most modern city, as among the hills of Arcadia three thousand years ago, men and women perceive in springtime that nature is awakening and at work in their bodies, just as it is in the beasts and trees. Carnival is still celebrated when the sap starts running.

Scientific knowledge of the persisting ancestral aspects of man's nature hardly goes beyond a vague awareness of their existence. Limited though it is, this knowledge is nevertheless sufficient to make it clear that medical and social philosophies are based on assumptions which should be reexamined. Some of these assumptions have come to light in their simplest and perhaps crudest forms during discussions on the medical problems posed by the necessity to make man more effective in the technological age, and also to prepare astronauts for life in space capsules.

At the London symposium mentioned above,[7] the participating scientists each had his own formula for modifying man by mechanical protheses, organ grafting, drug action, or eugenic control. But they hardly concerned themselves with the effects of these alterations on the aspects of man's nature which Dodds grouped under the adjective "irrational." A similar indifference appears in a recent article by a physician specialized in problems of space medicine. According to him, the sensible solution of these problems is to drastically modify man; the easiest approach being, in his view, to replace certain organs by mechanical parts more efficient for dial reading and better suited to electronic control. Natural, ordinary man could thus be converted into an "optiman."

Needless to say, the efficiency that biotechnologists aim at fostering in the various forms of "optiman" has little to do with the ancient but still vigorous biological human urges. Commentators in the daily press and in magazines have pointed out in many humorous or scornful articles that some scientists appear to be unaware of these fundamental needs of man's nature. The lay public has pragmatically recognized that man retains from his ancestral past certain needs and drives which, even though scientifically ill defined, nevertheless cry out for some form of expression.

There are also many tacit assumptions in the belief that the goal of technology, including medicine, should be to provide man with a sheltered environment in which he is protected as completely as possible from traumatic experiences. This assumption is dangerous because of the fact that many important traits of man's nature cannot develop normally, or remain in a healthy state, without constant stimulation and challenge.[8] Life at constant temperature through air conditioning, learning made effortless through mechanical aids, avoidance of conflicts through social adjustment, are examples of the means by which modern life eliminates or minimizes physiological or psychological effort, but by the same token causes an atrophy of man's adaptive mechanisms. Thus, while protection from stresses and effort may add to the pleasure or at least comfort of the moment, and while emotional neutrality minimizes social conflicts, the consequences of an excessively sheltered life are certainly unfavorable in the long run. They are even dangerous in that the human jelly fish becomes adjusted to a particular place and time, but loses his ability to readjust as surroundings change.

Scientific Knowledge and Human Experience

In contrast with the arts, science is usually identified with logic and reason. Indeed, a large part of scientific history obviously consists in the progressive unfolding of a logical process; each particular field of science has its own inner logic, which makes one fact derive from another. It is also true, on the other hand, that the growth of science presents many aspects which are essentially independent of logic. At any given period, scientists are profoundly influenced by the assumptions which they accept as a basis for their work, and by the goals which they pursue consciously or more often unconsciously. To a large extent, these assumptions and these goals are those of the social community as a whole.

The most influential assumption of modern science is that the best and indeed the only scientific approach to the study of natural phenomena and of living organisms is to divide them into fragments and to investigate elementary structures and properties in greater and greater detail. While it is repeatedly, and properly, pointed out that this analytical approach has been immensely fruitful in discoveries, there is far too little recognition of the disturbing fact that it has led to the neglect of other fields of science. Although everyone recognizes that the very existence of natural phenomena and of living organisms is the manifestation of the interplay between their constituent parts under the influence of environmental factors, hardly anything is known of the mechanisms through which natural systems function in an integrated manner.

In the course of reductionist analysis, the scientist tends to become so much involved intellectually and emotionally in the elementary fragments of the system, and in the analytical process itself, that he loses interest in the organism or the phenomenon which had been his first concern. For example, the student of man who starts from a question singled out because of its relevance to human life is likely to progress seriatim to the organ or function involved, then to the single cell, then to the cellular fragments, then to the molecular groupings or reactions, then to the individual molecules and atoms; and he would happily proceed if he knew enough to the elementary particles where matter and energy become indistinguishable. Problems of great interest obviously arise at each step in the disintegration of the original phenomenon. But in practically all cases the phenomenon itself is lost on the way, and the knowledge acquired in the course of its analysis usually throws little light on its determinants and modalities—let alone on the approach to its control. Scientists might find it useful now and then to evaluate their professional activities in the light of Kant's admonition, "To yield to every whim of curiosity, and to allow our passion for inquiry to be restrained by nothing but the limits of our ability, this shows an eagerness of mind not unbecoming to scholarship. But it is wisdom that has the merit of selecting from among the innumerable problems which present themselves, those whose solution is important to mankind."

Loss of interest in phenomena as they occur in Nature is found in practically all fields of science. It would be out of place to discuss here the consequences of this aspect of scientific professionalism for the advancement of knowledge. But it is relevant to the present theme to suggest that therein lies in part the cause of the estrangement of the general public from science. The primary interest of the public is in the phenomena of nature or in the living organisms, whereas the deepest commitment of the professional scientist is to the results of his analytical processes. In consequence, the scientist generally loses his public as he loses sight of the original problem.

Furthermore, whereas science was at first a method to deal with the world of matter and of life as man perceives it through his senses, much of the scientist's knowledge is now acquired through technical and mental processes which operate outside the range of immediate human experience. Emile Gilson stated in his William James Lectures at Harvard that "Every scientist naturally has the temper and the tastes of a specialist . . . . the natural tendency of science is not towards unity, but towards an ever more complete disintegration." This statement certainly describes a state of affairs which is increasingly prevalent, but it does not, in my opinion, deal with the most important aspect of the problem. A more disturbing aspect of modern science is that the specialist himself commonly loses contact with the aspect of reality which was his primary concern, whether it was matter, life or man.

In his own experience of the physical world, the physicist does not use his specialized knowledge for a richer or more subtle contact with reality; nor is the biologist rendered capable of perceiving the living experience more acutely because he is familiar with intermediate metabolism or x-ray diffraction patterns of contractile fibers. The theoretical physicist apparently finds it difficult to convert the mathematical formulae on which he depends into experiences or thoughts meaningful to his own senses and reason. The general biologist finds no trace of the creativeness of life in the macromolecules he isolates from the cell. The student of consciousness cannot relate the operations of the sense organs or of the nerve impulse to the emotion elicited by a fragrant rose or a romantic sunset.

There has been much talk during recent years of the lack of communication between the humanistic and the scientific aspects of knowledge. In reality, however, this disjunction is not so critical as is often suggested. Each and every one of us can and does learn many facts and concepts pertaining to areas of knowledge totally different from the one in which he is a specialist. The breakdown in communication is complete only when the concepts cannot be related to human experience. The physicist, the biologist, the humanist, and the layman can all find a common ground for discourse if they talk about matter, life, or man as perceived by the senses, or as apprehended in the form of images, analogies, and responses. But discussions of matter in terms of mathematical symbolism, or of life and man in terms of disintegrated components, cannot be related to any form of direct experience. Specialists must return to the original human basis of their work if they want to converse with mankind.[9]

Science and Technology as Independent Forces

Just as scientific knowledge is becoming alienated from human experience, so are its technological applications becoming increasingly alienated from human needs. Although modern technology appears at first sight but a spectacular extension of what it started out to be in the 18th and 19th centuries, in reality it is moving toward other goals. This change of focus is contributing to the disjunction between science and mankind.

The natural philosophers and sociologists of the Age of Reason were concerned with a few well defined problems of obvious importance for the welfare of the human race. Everywhere they saw misery and disease caused by acute shortages of food and of elementary conveniences; they observed that ignorance of the natural forces generates terror, superstitions and often acts of cruelty. The task they set for science was therefore to abolish the threat of scarcity, and to gain enough knowledge to help man face the natural world without fear. These goals were within the range of human experience. By making it possible to reach them, science was truly acting as a servant of mankind.

In contrast, science and the technologies derived from it now often function as forces independent of human goals. In many cases, as we have seen, knowledge creates concepts that man cannot restate in terms of his experience; and increasingly technology creates services and products that man does not really need. All too often, knowledge and technology pursue a course which is not guided by a pre-determined social philosophy. The knowledge of ionizing radiations and of atomic structure was developed by men with the highest ideals who can be regarded as saints of science, yet immense harm has come from their creations. The guilt for this harm cannot be placed on villains with selfish interests or bent on hurting mankind; it results rather from a political and social process which allows science to move blindly in the social arena.

Even though dangers are also inherent in the knowledge concerning automation, synthetic chemicals, or almost any other new technology, surprisingly little is done to evaluate the possible social consequences of these innovations. One dramatic illustration of this negligence is the research budget of the State Department. Science, lavishly endowed by public funds, produced nuclear weapons—the means by which man can now destroy himself. The problem of preventing this catastrophe is primarily the State Department's responsibility. Yet its total budget for policy research studies is negligible. Indeed, there is very little federal support for any kind of scholarly work on the explosive international issues now facing the world. Nor is there much recognition of the fact that the recent advances in medicine have created vast new problems which are essentially social, political, and economic rather than scientific. As E. M. Forster predicted in "The Machine Stops," technology moves on, but not on our lines; it proceeds, but not to our goals. It is urgent that science and technology be given goals of significance and value to man lest the sorcerer's apprentice be converted from a literary symbol into a terrifying reality.

The Industrial Revolution, with mass production of energy and its rapid injection into all aspects of social life, is everywhere beginning to disrupt the great dynamic processes which have so far maintained the earth in a state compatible with human life. Disruption of the water cycle is speeding water on its way to the sea and increasing its destructive action on land surfaces; denudation of the soil is creating dust bowls all over the earth; pollution of the air and of water is beginning to upset the biological balance and to damage human health. The medical sciences themselves are becoming so effective that they can affect unfavorably the fate of immense numbers of people and of their descendants, often creating new pathological processes as they control old diseases. Their greatest impact, probably, will be not so much on the size of the world population as on its genetic qualities, and on its other qualitative characteristics.

Needless to say, there is nothing fundamentally new in the fact that technology alters the relationship between man and nature. For many thousand years, man has modified his environment by using fire, farming the land, building houses, opening roads, and even controlling his reproduction. The all important difference, however, is that many modern applications of science have nothing to do with human biological needs and aim only at creating new demands, even though these be inimical to health, to happiness, or to the aspirations of mankind. Technology allowed to develop for its own sake often acts as a disruptive force which upsets the precarious relationships upon which civilizations have been built in the past. It creates new environmental conditions to which man finds it difficult to adapt, and which destroy some of the most valuable human attributes.

A process of adaptation is of course going on continuously between man and the new world he is creating. As we have seen, however, some important traits which are built into the fabric of man's nature are not likely to be eliminated, or significantly modified, despite all the changes which occur in his societies and ways of life. Even when man becomes an automated and urbane city dweller, his physiological processes remain geared to the daily rotation of the earth around its axis and to its annual rotation around the sun; the paleolithic bull which survives in his inner self still paws the earth whenever a threatening gesture is made on the social scene. The tragic paradox is that science fosters ways of life and manners of response which are often determined by technological expediency, whereas it hardly concerns itself with the fundamental characteristics and needs of man's nature.

While most human beings believe that the proper study of mankind is man, the scientific establishment has not tooled itself for this task. The great scientific institutions are geared for the analytical description of the body machine, which they approach in much the same spirit as they do simple inanimate objects. They pay little heed to the scientific study of man as a functioning entity, exhibiting all the complex responses that living entails. Nor do they pay much attention to the environmental factors which condition the manifestations of human life.

The disjunction between man's nature and the creations of science and technology inevitably manifests itself in social disturbances. In principle, these disturbances are not beyond the scope of scientific study; in practice, however, they have a low order of priority in the world of learning. The study of man as an integrated unit, and of the ecosystems in which he functions, is grossly neglected because it is not in the tradition which has dominated experimental science since the 17th century. Such a study would demand an intellectual approach, as well as research techniques and facilities, different from those which are fashionable and professionally profitable in the academic establishment.

Two historical reasons account for the tendency of scientists to neglect the problems posed by the complex situations found in the real world. One is that the simpler problems are more likely to yield clear results and rapid professional advance. The other reason is that until recently, the applications of science were direct and on the whole beneficial. Only during the past few decades has science become such a powerful force that any technological intervention affects simultaneously many aspects of human life.

Land conservation, water resources, urban development, the physiological and mental qualities of the human race are but a few among the immense problems created by the impact of scientific technology. It is therefore a moral obligation for the scientific establishment to devote itself in earnest to the study of ecosystems, both those of nature and those created by man. But ecosystems cannot be studied by the use of the oversimplified models which constitute the stock in trade of orthodox experimental science.

The urgency to escape from shackles of the scientific past is particularly apparent when attention turns to man himself. One of the strangest assumptions of present day biology is that knowledge of living man will automatically follow from so called "fundamental" studies of the elementary structures and reactions of fragments derived from living things. In reality, a very different kind of knowledge is needed to understand the nature of the cohesive forces which maintain man in an integrated state, physically, psychologically, and socially, and enable him to relate successfully to his environment. Hardly anything is known of man's adaptive potentialities, of the manner in which he responds to the stimuli which impinge on him early in his development and throughout his life, of the long range consequences of these responses not only for himself but for his descendants. There are countless problems ranging from those posed by the earlier sexual maturity of children to those involved in urban planning, which should and could be studied scientifically, yet have hardly any place in the curriculum of universities or research institutes.

Science for Man

Incoherence implies the breakdown of integrative relationships. One remedial measure is of course to establish better understanding and communication within the scientific community itself and between it and the public. But there is no knowledge of how this can be done effectively. At most, it is known that a few scientific books of distinction have been widely read, or at least have had a wide influence and are often quoted. A study of the reason for their success might provide some insight into the determinants of the public response to science, and indirectly into the aspects of science which have human values.

There are good reasons to believe that conceptual views of the world, even if purely theoretical, can have as much general appeal as utilitarian applications, and it is obvious of course that the appeal is even greater when the facts have some relevance to the problems which have always preoccupied mankind, whether these be concerned with the place of man in the cosmos or with his survival and welfare. But in any case, scientific communication demands more than the description of facts or the reporting of news. In science, just as in any other field, man can communicate with man only through the channels of shared experiences, or still better, through mutual hopes.

Through its emphasis on over-simplified models, the scientific community is betraying the very spirit of its vocation—namely, its professed concern with reality. Nature exists only in the form of complex ecosystems, and these constitute the environment which man perceives, and to which he responds. As human life becomes more dependent on technology, it will become more vulnerable to the slightest miscarriage or unforeseen consequence of innovations, hence the need for studies directed to the problems of interrelationships within complex ecosystems. Science will remain an effective method for the acquisition of knowledge meaningful to man, and consequently for social service only if its orthodox techniques can be supplemented by others which come closer to the human experience of reality, and to a kind of social action designed for fundamental human needs.

The study of natural and man-made ecosystems, as well as of man's responses to environmental forces, has as much intellectual dignity and deserves as much academic support as the study of isolated particles and elementary reactions. Only through a scientific knowledge of man's nature and of the ecosystems in which he functions can technology be usefully and safely woven into the fabric of society. Indeed, a truly human concept of technology might well constitute the force which will make science once more part of the universal human discourse, because technology at its highest level must integrate knowledge of the external world and of man's nature.

Since each particular field of science has its inner logic of growth, the scientific enterprise can long continue to move on its own momentum even though it becomes increasingly indifferent to man. Lacking worthwhile social goals, however, science may soon find itself floundering in a sea of irrelevancies. Eventually, it might even be rejected by ordinary men if they were to decide that its values are irrelevant and dangerous. "It seems to me entirely possible," stated recently a Sigma Xi lecturer, "that our society, which, for whatever motives, has invested not only immense sums of money but large amounts of spiritual faith in what it uninformedly conceives science to be, may become as thoroughly disillusioned and rebellious toward scientific and technological authoritarianism as early societies became rebellious towards regal authoritarianism."[10]

Despite its spectacular successes, science is not yet firmly established in the human mind. Its increasing alienation from the problems which are of deepest concern for mankind might well transform the anti-utopian outbursts so characteristic of our time from a literary exercise into an antiscience crusade. In its mildest form, such a crusade will at least continue to clamor for a moratorium on science, under the pretext that knowledge is accumulating faster than it can be digested and therefore is becoming dangerous. In reality, of course, there cannot be any retreat from science. Rather, public apprehension and hostility point to the need for an enlargement of science. Scientists must take more to heart the questions which deeply concern human beings; they must learn to give greater prominence to large human values when formulating their problems and their results. Fortunately, this is probably easier than is commonly believed because, as emphasized earlier, history shows that the broad implications of science can become integrated in the intellectual fabric of modern societies. Human cultures, like organisms and societies, depend for survival on their internal integration, an integration which can be achieved only to the extent that science remains meaningful to the living experience of man.

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Seminar Chairman
John S. Sherman
Associate Director for Extramural Programs
National Institutes of Health

Seminar Leader
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Director of Science Resources Project
George Washington University

Seminar Coordinator
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Employee Development Section
National Institutes of Health

Staff Assistant
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Personnel Management Branch
National Institutes of Health